

# PATENT ABSTRACTS OF JAPAN

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(54) SURFACE ACOUSTIC WAVE APPARATUS

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a surface acoustic wave apparatus which is not only improved in frequency-temperature characteristics by forming a SiO<sub>2</sub> film on an IDT (Interdigital Transducer) but can also surely obtain a desired characteristic resistance to cracks on a surface of the SiO film and having a large electrical-mechanical coupling factor and a small attenuation factor  $\alpha$ .

SOLUTION: In the apparatus, at least one IDT mainly composed of Cu is formed on a LiTaO<sub>3</sub> substrate of a 23°-46° rotation Y board, and the SiO<sub>2</sub> film is formed

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on the LiTaO<sub>3</sub> substrate in a manner to cover the IDT.

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**CLAIMS**

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[Claim(s)]

[Claim 1] Surface acoustic wave equipment characterized by having SiO<sub>2</sub> film  
which is formed on LiTaO<sub>3</sub> substrate of an Eulerian angle (0°-113  
degrees - 136 degrees, 0°-113 degrees), and said LiTaO<sub>3</sub> substrate, and was  
formed on said LiTaO<sub>3</sub> substrate so that at least one IDT which makes Cu a  
subject, and said IDT might be covered.

[Claim 2] Surface acoustic wave equipment according to claim 1 which whose  
thickness  $H/\lambda$  standardized on the wavelength of said surface wave of IDT  
is 0.01-0.08, and has the thickness standardized on the wavelength of the  
surface wave of said SiO<sub>2</sub> film in the range of 0.15-0.40.

[Claim 3] Surface acoustic wave equipment according to claim 1 the  
standardization thickness of said SiO<sub>2</sub> film and whose Eulerian angle of LiTaO<sub>3</sub>  
substrate said thickness  $H/\lambda$  of IDT is 0.01-0.08, and are either of the  
combination expressed below.

[Table 1]

| SiO <sub>2</sub> 膜厚 | LiTaO <sub>3</sub> のオイラー角 |
|---------------------|---------------------------|
| 0.15~0.18           | (0, 117~137, 0)           |
| 0.18~0.23           | (0, 117~136, 0)           |
| 0.23~0.28           | (0, 115~135, 0)           |
| 0.28~0.33           | (0, 113~133, 0)           |
| 0.33~0.38           | (0, 113~135, 0)           |
| 0.38~0.4            | (0, 113~132, 0)           |

[Claim 4] Surface acoustic wave equipment according to claim 3 characterized by theta of said Eulerian angle (0theta, 0) being in the range of the following formula (1) when standardization thickness of SiO<sub>2</sub> film is set to hs.

thetamin-2 degree< theta<=theta min+2 degree -- Formula (1)

However, among a formula (1), thetamin is a value expressed with following formula A-E, respectively, when standardization thickness H/lambda of IDT is the range of following (a) - (e).

(a) At the time of  $0 < H/\lambda \leq 0.01$  thetamin= $-139.713xhs^3+43.07132xhs^2-20.568011xhs+125.8314$  -- At the time of formula A(b) $0.01 < H/\lambda \leq 0.03$  thetamin= $-139.660xhs^3+46.02985xhs^2-21.141500xhs+127.4181$  -- At the time of formula B(c) $0.03 < H/\lambda \leq 0.05$  thetamin= $-139.607xhs^3+48.98838xhs^2-21.714900xhs+129.0048$  -- At the time of formula C(d) $0.05 < H/\lambda \leq 0.07$  thetamin= $-112.068xhs^3+39.60355xhs^2-21.186000xhs+129.9397$  -- At the time of formula D(e) $0.07 < H/\lambda \leq 0.09$  thetamin= $-126.954xhs^3+67.40488xhs^2-29.432000xhs+131.5686$  -- type E -- [Claim 5] Surface acoustic wave equipment according to claim 3 said standardization thickness of SiO<sub>2</sub> and whose Eulerian angle of LiTaO<sub>3</sub> substrate are either of the combination shown in the following table.

[Table 2]

| SiO <sub>2</sub> 膜厚 | LiTaO <sub>3</sub> のオイラー角 |
|---------------------|---------------------------|
| 0.15~0.18           | (0, 117~125, 0)           |
| 0.18~0.23           | (0, 117~125, 0)           |
| 0.23~0.28           | (0, 115~125, 0)           |
| 0.28~0.33           | (0, 113~125, 0)           |
| 0.33~0.38           | (0, 113~125, 0)           |
| 0.38~0.40           | (0, 113~125, 0)           |

[Claim 6] Surface acoustic wave equipment according to claim 1 to 5

characterized by using the leakage surface acoustic wave which uses an SH wave as a principal component as a surface acoustic wave.

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[Translation done.]

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**DETAILED DESCRIPTION**

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[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to the surface acoustic wave equipment which used rotation Y cut X propagation LiTaO<sub>3</sub> substrate for the detail more, and its manufacture approach about the surface acoustic wave equipment used for a resonator, a band-pass filter, etc.

[0002]

[Description of the Prior Art] In mobile transmitters, such as a cellular phone, the surface acoustic wave filter is used as the band-pass filter and duplexer of RF stage. As this kind of a surface acoustic wave filter, IDT (INTADEJITARUTORANSUDEYUSA) which consists of aluminum is formed on the LiTaO<sub>3</sub> substrate of 30 degrees - 50 degree rotation Y cut X propagation, and the surface acoustic wave filter using a leakage elastic wave is put in practical use.

[0003] However, with this surface acoustic wave filter, the frequency temperature characteristic was as bad as -30--40ppm/degree C, and that improvement was called for. Then, in order to improve the frequency temperature characteristic, after forming IDT which consists of aluminum on 30 degrees - 50 degree rotation Y cut X propagation LiTaO<sub>3</sub> substrate, the structure which carried out the laminating of the SiO<sub>2</sub> film further is proposed. The frequency temperature characteristic is improved by forming SiO<sub>2</sub> film.

[0004]

[Problem(s) to be Solved by the Invention] By the way, when forming IDT which consists of aluminum, in order to enlarge a reflection coefficient and an electromechanical coupling coefficient  $K^2$ , electrode layer thickness  $H/\lambda$  ( $H$  is thickness and  $\lambda$  is the wavelength of a surface wave) of IDT is made quite thick with 0.08-0.10. Thus, in the part shown in drawing 18 (a) since IDT which consists of aluminum is made quite thick, in order to improve the frequency temperature characteristic, when SiO<sub>2</sub> film was formed on it, as shown in drawing 18 (b), the big level difference might arise in SiO<sub>2</sub> film, and the crack might arise on SiO<sub>2</sub> film. Therefore, the filter shape of a surface acoustic wave filter tended to get worse according to generating of a crack.

[0005] In addition, since the electrode layer thickness of IDT which consists of aluminum is thick, the effectiveness which covers the irregularity of the electrode surface of IDT by formation of SiO<sub>2</sub> film was not enough, and the temperature characteristic may not fully have been improved by it.

[0006] Furthermore, the attenuation coefficient became large by formation of SiO<sub>2</sub> film, and degradation of a filter shape arose. In surface acoustic wave equipment using LiTaO<sub>3</sub> substrate of rotation Y cut X propagation in view of the present condition of the conventional technique which the purpose of this invention mentioned above It not only can improve the frequency temperature characteristic by formation of SiO<sub>2</sub> film, but it can reduce the electrode layer thickness of IDT. While being able to prevent the crack in SiO<sub>2</sub> film, an attenuation coefficient can also be reduced sharply. Therefore, it is in offering the

surface acoustic wave equipment with which electrical characteristics, such as the target filter shape, can be acquired, and the electromechanical coupling coefficient and reflection coefficient in IDT are made into sufficient magnitude, and its manufacture approach.

[0007]

[Means for Solving the Problem] According to the large aspect of affairs of this invention, it is formed on LiTaO<sub>3</sub> substrate of an Eulerian angle ( $0^{\circ}$  - 113 degrees - 136 degrees,  $0^{\circ}$  - 136 degrees), and said LiTaO<sub>3</sub> substrate, and the surface acoustic wave equipment characterized by having SiO<sub>2</sub> film formed on said LiTaO<sub>3</sub> substrate so that at least one IDT which makes Cu a subject, and said IDT might be covered is offered.

[0008] In this invention, in order that IDT may make Cu a subject, and since SiO<sub>2</sub> film is formed, an electromechanical coupling coefficient becomes large and a frequency temperature characteristic property is improved. Furthermore, since LiTaO<sub>3</sub> substrate of the above-mentioned specific Eulerian angle is used, an attenuation coefficient  $\alpha$  is reduced.

[0009] On the more restrictive aspect of affairs of this invention, thickness  $H/\lambda$  of IDT standardized on the wavelength of a surface wave is in the range of 0.01-0.08. Thickness  $H/\lambda$  standardized on the wavelength of the surface wave of SiO<sub>2</sub> film is made into the range of 0.15-0.40. In that case According to this invention, an electromechanical coupling coefficient and a reflection coefficient are large, and it has the good frequency temperature characteristic, and an attenuation coefficient is fully small and the surface acoustic wave equipment which the crack of SiO<sub>2</sub> film cannot produce easily can be offered certainly.

[0010] On the aspect of affairs of further others of this invention, said thickness  $H/\lambda$  of IDT is 0.12 or less, and let the standardization thickness of SiO<sub>2</sub>, and the Eulerian angle of said LiTaO<sub>3</sub> substrate be either of the combination expressed below.

[0011]

[Table 3]

| SiO <sub>2</sub> 膜厚 | LiTaO <sub>3</sub> のオイラー角 | より好ましくは         |
|---------------------|---------------------------|-----------------|
| 0.15~0.18           | (0, 117~137, 0)           | (0, 120~135, 0) |
| 0.18~0.23           | (0, 117~136, 0)           | (0, 118~133, 0) |
| 0.23~0.28           | (0, 115~135, 0)           | (0, 117~133, 0) |
| 0.28~0.33           | (0, 113~133, 0)           | (0, 115~132, 0) |
| 0.33~0.38           | (0, 113~135, 0)           | (0, 115~133, 0) |
| 0.38~0.4            | (0, 113~132, 0)           | (0, 115~130, 0) |

[0012] On still more nearly another specific aspect of affairs of this invention, if said standardization thickness of SiO<sub>2</sub> is set to  $h_s$ , let  $\theta$  of said Eulerian angle ( $0\theta$ , 0) be the range of the following formula (1).

$\theta_{\min} - 2 \text{ degree} < \theta \leq \theta_{\min} + 2 \text{ degree}$  -- Formula (1)

However, among a formula (1),  $\theta_{\min}$  is a value expressed with following formula A-E, respectively, when standardization thickness  $H/\lambda$  of IDT is in the range of following (a) - (e).

(a) At the time of  $0 < H/\lambda \leq 0.01$   $\theta_{\min} = -139.713xh_s^3 + 43.07132xh_s^2 - 20.568011xh_s + 125.8314$  -- At the time of formula A(b)  $0.01 < H/\lambda \leq 0.03$   $\theta_{\min} = -139.660xh_s^3 + 46.02985xh_s^2 - 21.141500xh_s + 127.4181$  -- At the time of formula B(c)  $0.03 < H/\lambda \leq 0.05$   $\theta_{\min} = -139.607xh_s^3 + 48.98838xh_s^2 - 21.714900xh_s + 129.0048$  -- At the time of formula C(d)  $0.05 < H/\lambda \leq 0.07$   $\theta_{\min} = -112.068xh_s^3 + 39.60355xh_s^2 - 21.186000xh_s + 129.9397$  -- At the time of formula D(e)  $0.07 < H/\lambda \leq 0.09$   $\theta_{\min} = -126.954xh_s^3 + 67.40488xh_s^2 - 29.432000xh_s + 131.5686$  -- Let said standardization thickness of SiO<sub>2</sub>, and the Eulerian angle of LiTaO<sub>3</sub> substrate further be either of the combination shown in the following table on other specific aspects of affairs of formula E this invention.

[0013]

[Table 4]

| SiO <sub>2</sub> 膜厚 | LiTaO <sub>3</sub> のオイラー角 |
|---------------------|---------------------------|
| 0.15~0.18           | (0, 117~125, 0)           |
| 0.18~0.23           | (0, 117~125, 0)           |
| 0.23~0.28           | (0, 115~125, 0)           |
| 0.28~0.33           | (0, 113~125, 0)           |
| 0.33~0.38           | (0, 113~125, 0)           |
| 0.38~0.40           | (0, 113~125, 0)           |

[0014] In the case of the combination shown in the above-mentioned table (i.e.,



when theta of an Eulerian angle is made into 125 degrees or less), an electromechanical coupling coefficient  $K_2$  can be enlarged further. With the surface acoustic wave equipment concerning this invention, preferably, a leakage surface acoustic wave is used as a surface wave, it excels in the frequency temperature characteristic according to this invention, and the surface acoustic wave equipment with a small propagation loss which has IDT with big electromechanical coupling coefficient and reflection coefficient can be offered.

[0015]

[Embodiment of the Invention] Hereafter, this invention is clarified by explaining the concrete example of this invention, referring to a drawing.

[0016] Drawing 1 is a top view for explaining the vertical joint resonator filter as surface acoustic wave equipment concerning one example of this invention. Surface acoustic wave equipment 11 has the structure in which IDT(s) 13a and 13b and Reflectors 14a and 14b were formed on the top face of LiTaO<sub>3</sub> substrate 12. Moreover, SiO<sub>2</sub> film 15 is formed so that IDT(s) 13a and 13b and Reflectors 14a and 14b may be covered. In addition, as LiTaO<sub>3</sub> substrate 12, 23 degrees - 46 degree rotation Y cut LiTaO<sub>3</sub> substrate is used. In this rotation Y cut X propagation LiTaO<sub>3</sub> substrate of a cut angle out of range, an attenuation coefficient is large and TCF also gets worse.

[0017] IDT(s) 13a and 13b and Reflectors 14a and 14b consist of Cu with a high consistency compared with aluminum. As mentioned above, since IDT(s) 13a and 13b and Reflectors 14a and 14b are constituted by Cu with a high consistency compared with aluminum, even if it is the case where thickness of IDT(s) 13a and 13b and Reflectors 14a and 14b is made thin compared with the case where aluminum is used, an electromechanical coupling coefficient and a reflection coefficient can be raised.

[0018] Drawing 16 is drawing showing the reflection factor per electrode layer of Cu electrode in case the standardization thickness of SiO<sub>2</sub> film is 0.20, and aluminum electrode, and relation with electrode layer thickness. Since the reflection factor per electrode finger is raised when the electrode which consists

of Cu is used compared with the electrode which consists of aluminum used conventionally, as shown in drawing 16, the number of the electrode finger in a reflector can also be reduced. Therefore, the miniaturization of a reflector, as a result the miniaturization of surface wave equipment can be attained.

[0019] And since electrode layer thickness can be made thin as mentioned above, generating of a crack based on the level difference in SiO<sub>2</sub> film 15 formed on IDT13a and 13b mentioned above can be controlled certainly. About the thickness of SiO<sub>2</sub> film 15, it is desirable that the range of thickness  $H/\lambda$  standardized on the wavelength of a surface wave is 0.15-0.40 so that clearly from the below-mentioned example of an experiment. By making it this range, an attenuation coefficient can be sharply made small and low loss-ization is attained from the case where SiO<sub>2</sub> film is not formed.

[0020] As for thickness  $H/\lambda$  standardized on the wavelength of the surface wave of IDT(s) 13a and 13b, 0.01-0.08 are desirable so that it may mention later. With the surface acoustic wave equipment which this invention requires, as mentioned above, IDT(s) 13a and 13b are constituted by Cu on LiTaO<sub>3</sub> substrate 12, and this electrode layer thickness of IDT(s) 13a and 13b can be made thin. Therefore, generating of the level difference in SiO<sub>2</sub> film can be controlled, and a crack can be prevented certainly. Since LiTaO<sub>3</sub> substrate of the Eulerian angle of further the above-mentioned specification is used, an attenuation coefficient can be sharply made small, and low loss-ization is attained. Moreover, the good frequency temperature characteristic is realized by formation of SiO<sub>2</sub> film 15.

This is explained based on the concrete example of an experiment.

[0021] The leakage surface acoustic wave (LSAW) other than a Rayleigh wave is shown in the surface wave transmitted in LiTaO<sub>3</sub> substrate. A leakage surface acoustic wave is spread emitting energy in a substrate, although the electromechanical coupling coefficient of acoustic velocity is large early compared with a Rayleigh wave. Therefore, a leakage surface acoustic wave has an attenuation coefficient leading to a propagation loss.

[0022] Drawing 3 shows the relation between theta of the Eulerian angle (0

degree, theta, 0 degree) in rotation Y cut X propagation LiTaO<sub>3</sub> substrate, and the attenuation coefficient alpha when a substrate front face short-circuits electrically. In addition, an angle of rotation = there is relation of theta-90 degrees.

[0023] Like being clear from drawing 3 , in the range whose theta of an Eulerian angle is 124 degrees - 126 degrees, although an attenuation coefficient alpha is small, if out of range, this thing [ that an attenuation coefficient alpha becomes large ] is understood. Moreover, when IDT which consists of aluminum with comparatively thick thickness is used, it is known that an attenuation coefficient will become small at theta= 129 degrees - 136 degrees. Therefore, when IDT which consists of aluminum was used conventionally, the thing of the range whose theta of an Eulerian angle is 129 degrees - 136 degrees was used as LiTaO<sub>3</sub> substrate.

[0024] Drawing 2 shows the relation between theta of an Eulerian angle, and an electromechanical coupling coefficient K<sub>2</sub>. The big electromechanical coupling coefficient K<sub>2</sub> is obtained in the range whose theta of an Eulerian angle is 100 degrees - 120 degrees so that clearly from drawing 2 . However, in theta= 100 degrees - 120 degrees, an attenuation coefficient alpha is large and LiTaO<sub>3</sub> substrate which is theta= 100 degrees - 120 degrees cannot be used for surface acoustic wave equipment so that clearly from drawing 3 .

[0025] Drawing 4 indicates relation with an electromechanical coupling coefficient K<sub>2</sub> to be standardization thickness H/lambda of Cu film at the time of forming IDT which consists of Cu on 36-degree rotation Y cut X propagation LiTaO<sub>3</sub> substrate (they being (0 degree, 126 degrees, 0 degree) at an Eulerian angle). In addition, lambda shall show the wavelength in the center frequency of surface acoustic wave equipment.

[0026] It turns out that thickness H/lambda of Cu film becomes 1.5 or more times in the range of 0.01-0.10 compared with the case (H/lambda = 0) where Cu film is not formed for the electromechanical coupling coefficient K<sub>2</sub> so that clearly from drawing 4 . Moreover, compared with the case where Cu film is not formed for the thickness of Cu film in H/lambda =0.02-0.08, it turns out that an

electromechanical coupling coefficient  $K_2$  serves as a value of 1.8 times or more, and thickness  $H/\lambda$  of Cu film serves as a twice [ in case Cu film is not formed / more than ] as many value as this in 0.03-0.06. Furthermore, as compared with aluminum used conventionally,  $H/\lambda$  takes the maximal value by about 0.04 and thin thickness, and the value also has it compared with aluminum. [ large ]

[0027] If standardization thickness  $H/\lambda$  of Cu film exceeds 0.08, production of IDT which consists of Cu film will become difficult. Therefore, as for the thickness of IDT which can obtain a big electromechanical coupling coefficient, and consists of Cu film since production of IDT is easy, it is desirable that it is the range of 0.01-0.08, and it considers as the range of 0.03-0.06 preferably [ it is more desirable and ] to 0.02 to 0.08, and a pan.

[0028] Next, change of the frequency temperature coefficient TCF at the time of forming SiO<sub>2</sub> film on LiTaO<sub>3</sub> substrate is shown in drawing 5 . drawing 5 -- an Eulerian angle (0 degree, 113 degrees, 0 degree) -- and (0 degree, 126 degrees, 0 degree) (0 degree, 129 degrees, 0 degree) shows the relation between standardization thickness  $H/\lambda$  of SiO<sub>2</sub> film in case SiO<sub>2</sub> film is formed on three kinds of LiTaO<sub>3</sub> substrates, and TCF. In addition, the electrode is not formed here.

[0029] When theta is any which are 113 degrees, 126 degrees, and 129 degrees so that clearly from drawing 5 , it turns out that standardization thickness  $H/\lambda$  of SiO<sub>2</sub> film serves as range whose TCF is -20-+17ppm/degree C in the range of 0.15-0.45. But in order for membrane formation of SiO<sub>2</sub> film to take time amount, as for thickness  $H/\lambda$  of SiO<sub>2</sub> film, 0.15-0.40 are desirable.

[0030] Although it was known that TCF(s), such as a Rayleigh wave, will be improved by forming SiO<sub>2</sub> film on LiTaO<sub>3</sub> substrate, the electrode which consists of Cu is formed on LiTaO<sub>3</sub> substrate, and there is no report in which it actually experimented in consideration of the attenuation coefficient of the thickness of the electrode which consists of Cu, the thickness of SiO<sub>2</sub>, a cut angle, and a leakage elastic wave in the structure which carried out the laminating of the SiO<sub>2</sub>

film further.

[0031] Drawing 6 shows change of the attenuation coefficient  $\alpha$  when the electrode with which standardization thickness  $H/\lambda$  consists of 0.10 or less Cu, and standardization thickness  $H/\lambda$  form SiO<sub>2</sub> film of 0-0.5 on the LiTaO<sub>3</sub> substrate of an Eulerian angle (0 degree, 120 degrees, 0 degree). When thickness  $H/\lambda$  of SiO<sub>2</sub> film is [ thickness  $H/\lambda$  of 0.2 to 0.40 and Cu film ] 0.01-0.10 so that clearly from drawing 6 , it turns out that the attenuation coefficient  $\alpha$  is small.

[0032] On the other hand, on the LiTaO<sub>3</sub> substrate of the Eulerian angle of (0 degree, 135 degrees, 0 degree), standardization thickness  $H/\lambda$  forms Cu film of 0-0.10, and drawing 7 shows change of the attenuation coefficient  $\alpha$  when standardization thickness  $H/\lambda$  forms SiO<sub>2</sub> film of 0-0.5 further.

[0033] Though the thickness of Cu film and the thickness of SiO<sub>2</sub> film are changed as mentioned above when LiTaO<sub>3</sub>  $\theta = 135$ -degree substrate is used so that clearly from drawing 7 , it turns out that an attenuation coefficient  $\alpha$  is large.

[0034] That is, in order to realize good TCF, a big electromechanical coupling coefficient, and a small attenuation coefficient, it turns out that it is necessary to combine the cut angle of LiTaO<sub>3</sub> substrate, i.e., an Eulerian angle, the thickness of SiO<sub>2</sub> film, and the thickness of the electrode which consists of Cu, respectively so that it may be the optimal.

[0035] Standardization thickness  $H/\lambda$  of SiO<sub>2</sub> film is 0.1, 0.15, 0.2, 0.25, 0.3, 0.35, and 0.4 or 0.45, and drawing 8 - drawing 15 show  $\theta$  when standardization thickness  $H/\lambda$  forms 0.08 or less Cu film on LiTaO<sub>3</sub> substrate, and relation with an attenuation coefficient  $\alpha$ , respectively.

[0036] If the thickness of SiO<sub>2</sub> film and  $\theta$  of an Eulerian angle are chosen as shown in the following table 5 when thickness  $H/\lambda$  of Cu film is set to 0.01-0.08 so that clearly from drawing 8 - drawing 15 , the frequency temperature characteristic TCF is good, and an electromechanical coupling coefficient is large, and it turns out that an attenuation coefficient  $\alpha$  can be controlled effectively.

Desirably, a much more good property can be acquired by choosing the more desirable Eulerian angle on the right-hand side of the following table 3.

[0037]

[Table 5]

| SiO <sub>2</sub> 膜厚 | LiTaO <sub>3</sub> のオイラー角 | より好ましくは         |
|---------------------|---------------------------|-----------------|
| 0.15~0.18           | (0, 117~137, 0)           | (0, 120~135, 0) |
| 0.18~0.23           | (0, 117~136, 0)           | (0, 118~133, 0) |
| 0.23~0.28           | (0, 115~135, 0)           | (0, 117~133, 0) |
| 0.28~0.33           | (0, 113~133, 0)           | (0, 115~132, 0) |
| 0.33~0.38           | (0, 113~135, 0)           | (0, 115~133, 0) |
| 0.38~0.4            | (0, 113~132, 0)           | (0, 115~130, 0) |

[0038] Moreover, when theta of an Eulerian angle becomes 125 degrees or less so that clearly from drawing 2, it turns out that an electromechanical coupling coefficient k<sub>2</sub> becomes remarkably large. Therefore, it turns out that the combination of the standardization thickness of SiO<sub>2</sub> film and the Eulerian angle which are shown in the following table 6 is desirable more preferably.

[0039]

[Table 6]

| SiO <sub>2</sub> 膜厚 | LiTaO <sub>3</sub> のオイラー角 |
|---------------------|---------------------------|
| 0.15~0.18           | (0, 117~125, 0)           |
| 0.18~0.23           | (0, 117~125, 0)           |
| 0.23~0.28           | (0, 115~125, 0)           |
| 0.28~0.33           | (0, 113~125, 0)           |
| 0.33~0.38           | (0, 113~125, 0)           |
| 0.38~0.40           | (0, 113~125, 0)           |

[0040] Furthermore, the result of having searched for the Eulerian angle from which an attenuation coefficient serves as 0 or min, i.e., thetamin, from the result shown in drawing 5 - drawing 14 from standardization thickness H/lambda of the standardization thickness h<sub>s</sub> of SiO<sub>2</sub> film and Cu film is shown in drawing 17.

[0041] When standardization thickness H/lambda of Cu film approximates each curve shown in drawing 17 in 0, 0.02, 0.04, and 0.06 and 0.08 by the cubic polynomial, following formula A-E is obtained.

(a) At the time of  $0 < H/\lambda \leq 0.01$  thetamin =  $-139.713xhs^3 + 43.07132xhs^2 - 20.568011xhs + 125.8314$  -- At the time of formula A(b)  $0.01 < H/\lambda \leq 0.03$

$\theta_{\text{amin}} = -139.660xhs^3 + 46.02985xhs^2 - 21.141500xhs + 127.4181$  -- At the time of formula B(c)  $0.03 < H/\lambda \leq 0.05$   $\theta_{\text{amin}} = -139.607xhs^3 + 48.98838xhs^2 - 21.714900xhs + 129.0048$  -- At the time of formula C(d)  $0.05 < H/\lambda \leq 0.07$   $\theta_{\text{amin}} = -112.068xhs^3 + 39.60355xhs^2 - 21.186000xhs + 129.9397$  -- At the time of formula D(e)  $0.07 < H/\lambda \leq 0.09$   $\theta_{\text{amin}} = -126.954xhs^3 + 67.40488xhs^2 - 29.432000xhs + 131.5686$  -- type E -- therefore, preferably Although it is desirable to be referred to as  $\theta_{\text{amin}}$  shown by the formula A mentioned above - Formula E as for  $\theta$  of an Eulerian angle ( $0^\circ$ ,  $\theta$ ), if it is  $\theta_{\text{amin}} - 2^\circ < \theta \leq \theta_{\text{amin}} + 2^\circ$ , it can make an attenuation coefficient small effectively.

[0042] In addition, although IDT may consist of only Cu(s), as long as Cu is made into a subject, it may be constituted from this invention by the layered product of Cu alloy, or Cu and other metals. IDT which makes Cu a subject should just satisfy  $\rho(\text{Cu}) \times 0.7 \leq \rho(\text{average}) \leq \rho(\text{Cu}) \times 1.3$ ,  $6.25 \text{ g/cm}^3$  [ i.e., ],  $\rho(\text{average}) \leq 11.6 \text{ g/cm}^3$ , if mean density of an electrode is set to  $\rho(\text{average})$ . In addition, the laminating of the electrode which consists of metals, such as W, Ta, Au, Pt, Ag, or Cr with a larger consistency than aluminum, may be carried out so that  $\rho(\text{average})$  of the whole electrode may become the above-mentioned range on Cu or in the bottom. Also in such a case, the same effectiveness as the case of Cu electrode monolayer is acquired.

[0043] In the above-mentioned experiment, although LiTaO<sub>3</sub> substrate of an Eulerian angle ( $0^\circ$ ,  $\theta$ ,  $0^\circ$ ) was used, in the Eulerian angle of a substrate ingredient,  $0^\circ$ -degree dispersion usually occurs. Within the limits ( $0^\circ$ ,  $113^\circ$  -  $136^\circ$ ,  $0^\circ$ ) it is such dispersion, the effectiveness of this invention is acquired also in LiTaO<sub>3</sub> substrate.

[0044] In addition, this invention is applicable to various surface-wave equipments, such as not only the vertical joint resonator mold surface acoustic wave filter shown in drawing 1 but a surface acoustic wave resonator, a horizontal joint mold surface-wave filter, a ladder mold filter, a lattice mold filter, etc.

[0045]

[Effect of the Invention] With the surface acoustic wave equipment concerning this invention, on the LiTaO<sub>3</sub> substrate of an Eulerian angle ( $0^{\circ}$  - 136 degrees,  $0^{\circ}$  - 136 degrees) Since at least one IDT which makes Cu a subject is formed, and SiO<sub>2</sub> film is formed on the LiTaO<sub>3</sub> substrate so that this IDT may be covered, The surface acoustic wave equipment with few propagation losses with which an electromechanical coupling coefficient is large with equipment, and it excels in the temperature characteristic, and the attenuation coefficient  $\alpha$  was reduced can be offered.

[0046] Moreover, in this invention, the thickness standardized on the wavelength of the surface wave of IDT is 0.01-0.08, when the standardization thickness of SiO<sub>2</sub> film is in the range of 0.15-0.40, an electromechanical coupling coefficient can be raised further and the good temperature characteristic can be realized.

[0047] Furthermore, thickness  $H/\lambda$  of IDT is 0.01-0.08, Table 1 and when [ as more preferably shown in Table 2, ] standardization thickness  $H/\lambda$  of  $\theta$  of the Eulerian angle of LiTaO<sub>3</sub> substrate and SiO<sub>2</sub> film is chosen, an electromechanical coupling coefficient is larger still, an attenuation coefficient  $\alpha$  is small, and the surface acoustic wave equipment which was further excellent in the frequency temperature characteristic can be offered.

[0048] Moreover,  $\theta$  of the Eulerian angle ( $\theta$ ,  $0^{\circ}$ ) of LiTaO<sub>3</sub> substrate is size from  $\theta_{\min}-2^{\circ}$ , and, in the case of not more than  $\theta_{\min}+2^{\circ}$  degree, an attenuation coefficient is made still smaller. Therefore, a propagation loss may be made still smaller.

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[Translation done.]

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## DESCRIPTION OF DRAWINGS

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### [Brief Description of the Drawings]

[Drawing 1] The top view showing the surface acoustic wave equipment concerning one example of this invention.

[Drawing 2] Drawing showing the relation of the theta and the electromechanical coupling coefficient  $K_2$  on the LiTaO<sub>3</sub> substrate of an Eulerian angle (0 degree, theta, 0 degree).

[Drawing 3] Drawing showing the relation of the theta and the attenuation coefficient alpha on the LiTaO<sub>3</sub> substrate of an Eulerian angle (0 degree, theta, 0 degree).

[Drawing 4] Drawing showing relation with an electromechanical coupling coefficient  $K_2$  with Cu at the time of forming the electrode which consists of various Cu(s) or aluminum film of thickness on the LiTaO<sub>3</sub> substrate of an Eulerian angle (0 degree, 126 degrees, 0 degree), or standardization thickness  $H/\lambda$  of aluminum film.

[Drawing 5] an Eulerian angle (0 degree, 113 degrees, 0 degree) -- and (0 degree, 126 degrees, 0 degree) (0 degree, 129 degrees, 0 degree) drawing showing the relation between standardization thickness  $H/\lambda$  of SiO<sub>2</sub> film at the time of forming SiO<sub>2</sub> film of various thickness in three kinds of LiTaO<sub>3</sub> substrates, without forming an electrode, and the frequency temperature coefficient TCF.

[Drawing 6] Drawing showing change of the attenuation coefficient alpha at the time of forming Cu film of 0.1 or less standardization thickness on the LiTaO<sub>3</sub> substrate of an Eulerian angle (0 degree, 120 degrees, 0 degree), and forming

SiO<sub>2</sub> film of the standardization thickness of 0-0.5.

[Drawing 7] Drawing showing change of the attenuation coefficient  $\alpha$  at the time of forming Cu film of 0.1 or less standardization thickness on the LiTaO<sub>3</sub> substrate of an Eulerian angle (0 degree, 135 degrees, 0 degree), and forming SiO<sub>2</sub> film of the standardization thickness of 0-0.5.

[Drawing 8] Drawing showing change of an attenuation coefficient  $\alpha$  when standardization thickness  $H/\lambda$  forms 0.1 or less various Cu film on the LiTaO<sub>3</sub> substrate of an Eulerian angle (0 degree,  $\theta$ , 0 degree) and standardization thickness  $H/\lambda$  carries out the laminating of the SiO<sub>2</sub> film of 0.1.

[Drawing 9] Drawing showing change of an attenuation coefficient  $\alpha$  when standardization thickness  $H/\lambda$  forms 0.1 or less various Cu film on the LiTaO<sub>3</sub> substrate of an Eulerian angle (0 degree,  $\theta$ , 0 degree) and standardization thickness  $H/\lambda$  carries out the laminating of the SiO<sub>2</sub> film of 0.15.

[Drawing 10] Drawing showing change of an attenuation coefficient  $\alpha$  when standardization thickness  $H/\lambda$  forms 0.1 or less various Cu film on the LiTaO<sub>3</sub> substrate of an Eulerian angle (0 degree,  $\theta$ , 0 degree) and standardization thickness  $H/\lambda$  carries out the laminating of the SiO<sub>2</sub> film of 0.2.

[Drawing 11] Drawing showing change of an attenuation coefficient  $\alpha$  when standardization thickness  $H/\lambda$  forms 0.1 or less various Cu film on the LiTaO<sub>3</sub> substrate of an Eulerian angle (0 degree,  $\theta$ , 0 degree) and standardization thickness  $H/\lambda$  carries out the laminating of the SiO<sub>2</sub> film of 0.25.

[Drawing 12] Drawing showing change of an attenuation coefficient  $\alpha$  when standardization thickness  $H/\lambda$  forms 0.1 or less various Cu film on the LiTaO<sub>3</sub> substrate of an Eulerian angle (0 degree,  $\theta$ , 0 degree) and standardization thickness  $H/\lambda$  carries out the laminating of the SiO<sub>2</sub> film of 0.3.

[Drawing 13] Drawing showing change of an attenuation coefficient  $\alpha$  when standardization thickness  $H/\lambda$  forms 0.1 or less various Cu film on the LiTaO<sub>3</sub> substrate of an Eulerian angle (0 degree,  $\theta$ , 0 degree) and standardization thickness  $H/\lambda$  carries out the laminating of the SiO<sub>2</sub> film of 0.35.

[Drawing 14] Drawing showing change of an attenuation coefficient  $\alpha$  when standardization thickness  $H/\lambda$  forms 0.1 or less various Cu film on the LiTaO<sub>3</sub> substrate of an Eulerian angle (0 degree,  $\theta$ , 0 degree) and standardization thickness  $H/\lambda$  carries out the laminating of the SiO<sub>2</sub> film of 0.4.

[Drawing 15] Drawing showing change of an attenuation coefficient  $\alpha$  when standardization thickness  $H/\lambda$  forms 0.1 or less various Cu film on the LiTaO<sub>3</sub> substrate of an Eulerian angle (0 degree,  $\theta$ , 0 degree) and standardization thickness  $H/\lambda$  carries out the laminating of the SiO<sub>2</sub> film of 0.45.

[Drawing 16] Drawing showing the relation of the reflection factor per electrode finger and electrode layer thickness in the electrode which consists of an electrode which consists of aluminum in case the standardization thickness of SiO<sub>2</sub> film is 0.02, and Cu.

[Drawing 17] Drawing showing the relation between standardization thickness  $H_s/\lambda$  of SiO<sub>2</sub> film for realizing the  $\theta$  from which an attenuation coefficient serves as 0 or min, and standardization thickness  $H/\lambda$  of Cu film.

[Drawing 18] (a) And (b) is drawing showing the scanning electron microscope photograph to which it is drawing for explaining the trouble of conventional surface acoustic wave equipment, and the condition of the front face of SiO<sub>2</sub> film of (b) is indicated to be (a) after membrane formation before membrane formation of SiO<sub>2</sub> film.

[Description of Notations]

11 -- Surface acoustic wave equipment

12 -- LiTaO<sub>3</sub> substrate

13a, 13 b--IDT

15 -- SiO<sub>2</sub> film

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[Translation done.]

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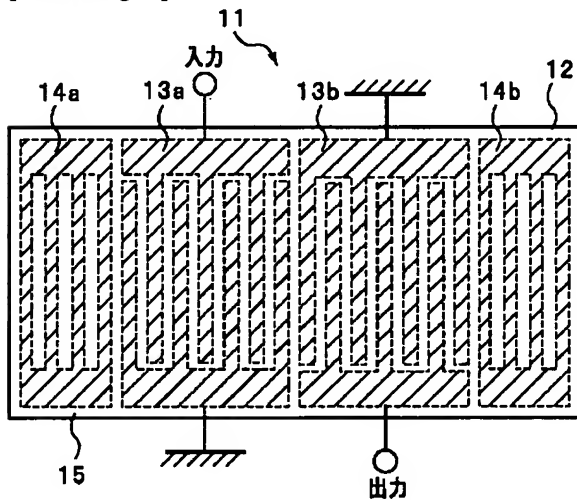
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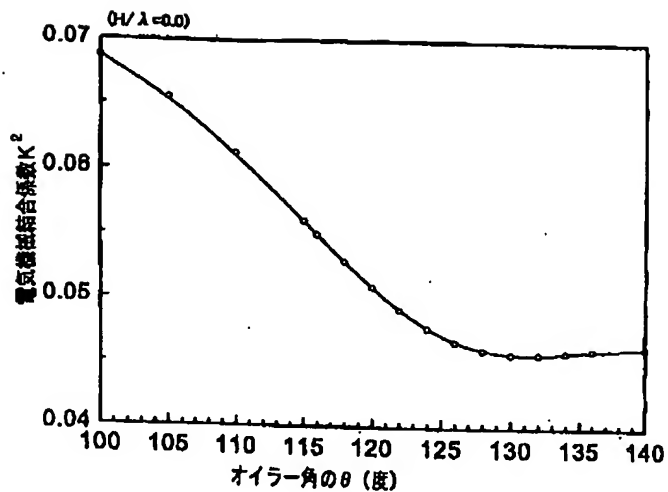
## DRAWINGS

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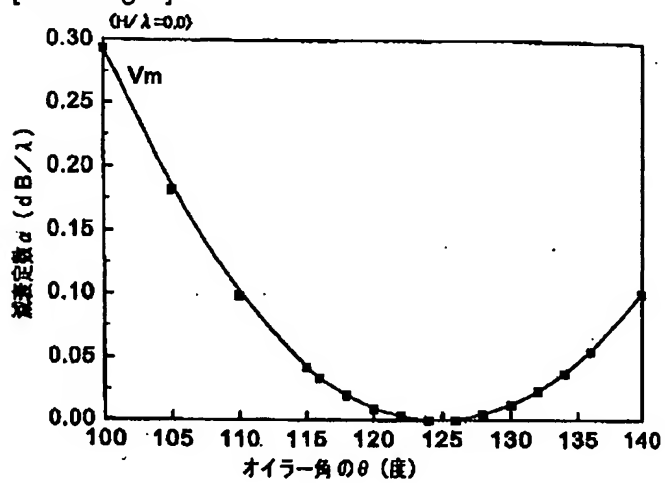
[Drawing 1]



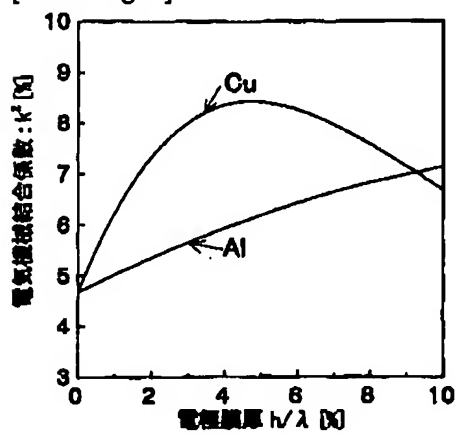
[Drawing 2]



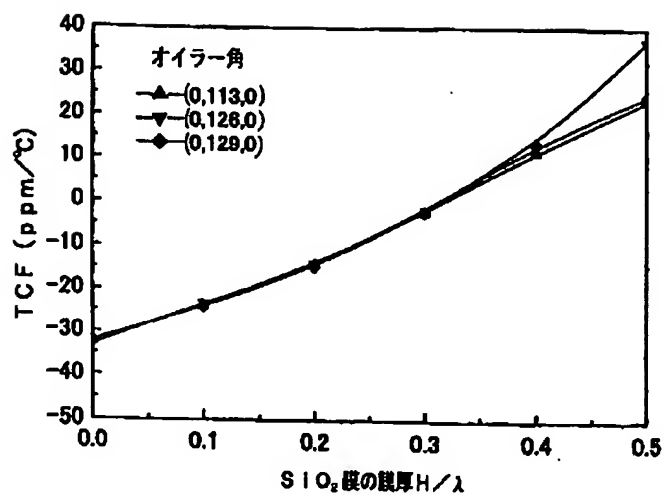
[Drawing 3]



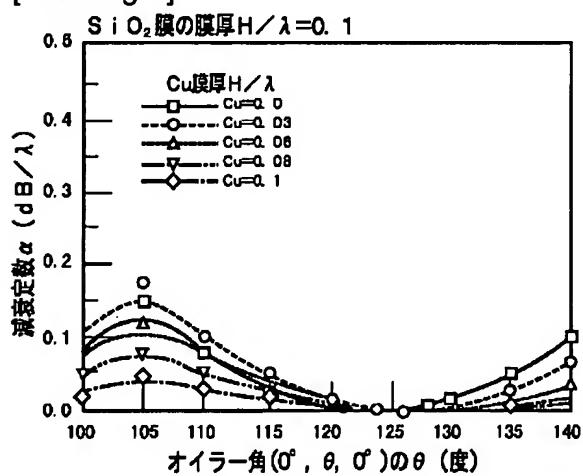
[Drawing 4]



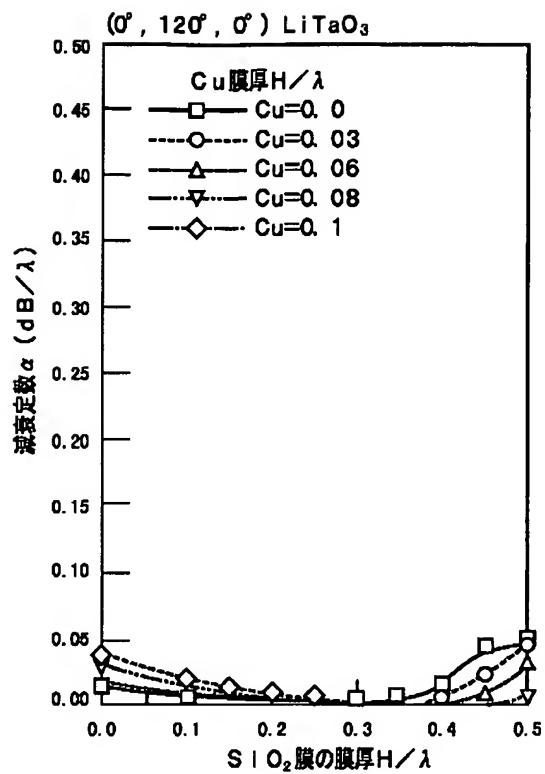
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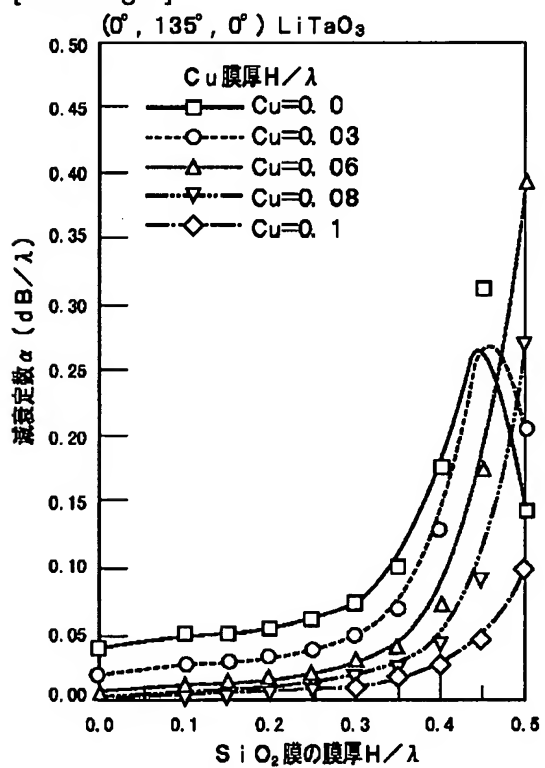
[Drawing 8]



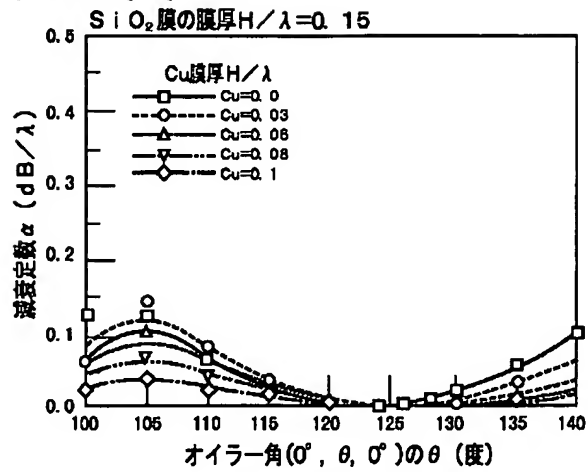
[Drawing 6]



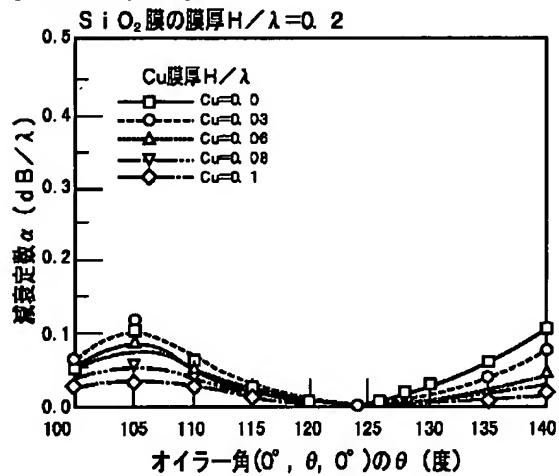
[Drawing 7]



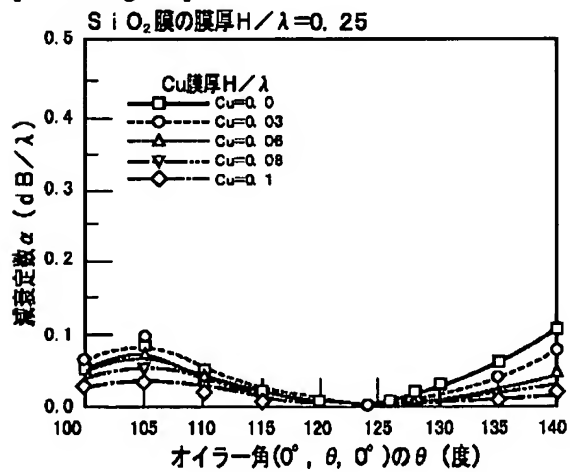
[Drawing 9]



[Drawing 10]

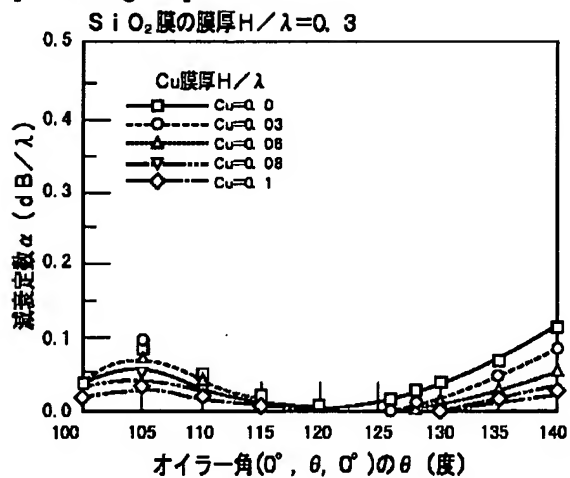


[Drawing 11]

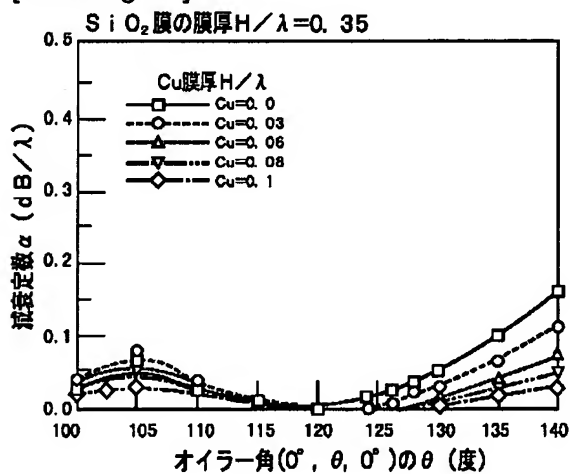




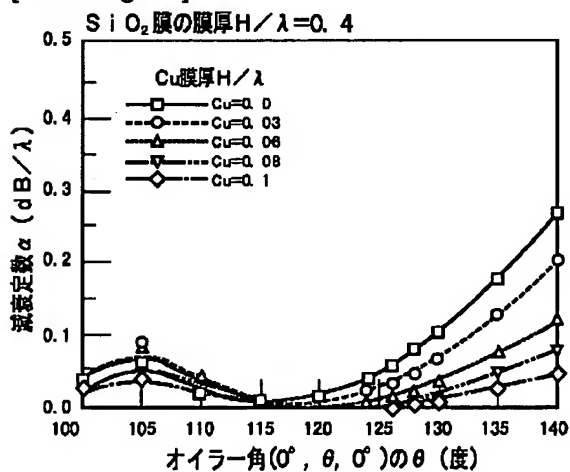
[Drawing 12]



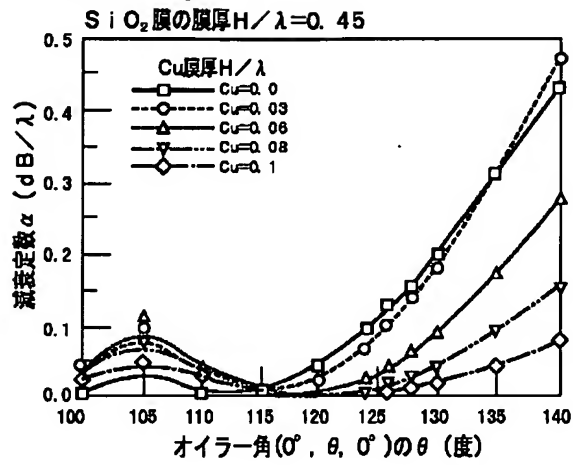
[Drawing 13]



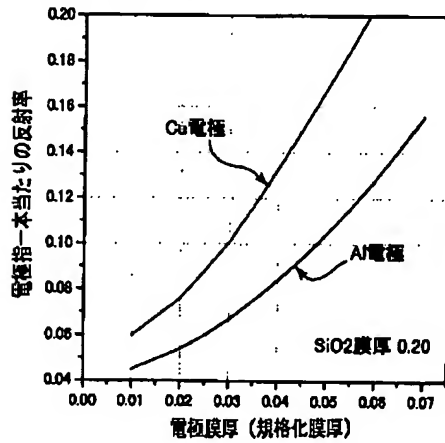
[Drawing 14]



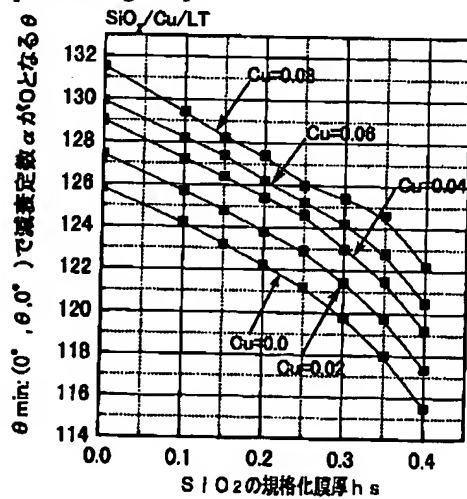
[Drawing 15]



[Drawing 16]

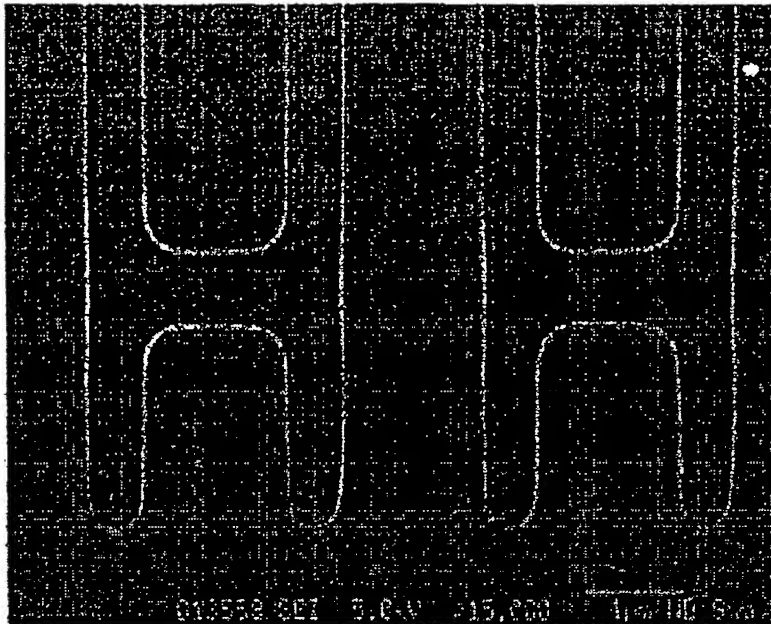


[Drawing 17]



[Drawing 18]

(a)



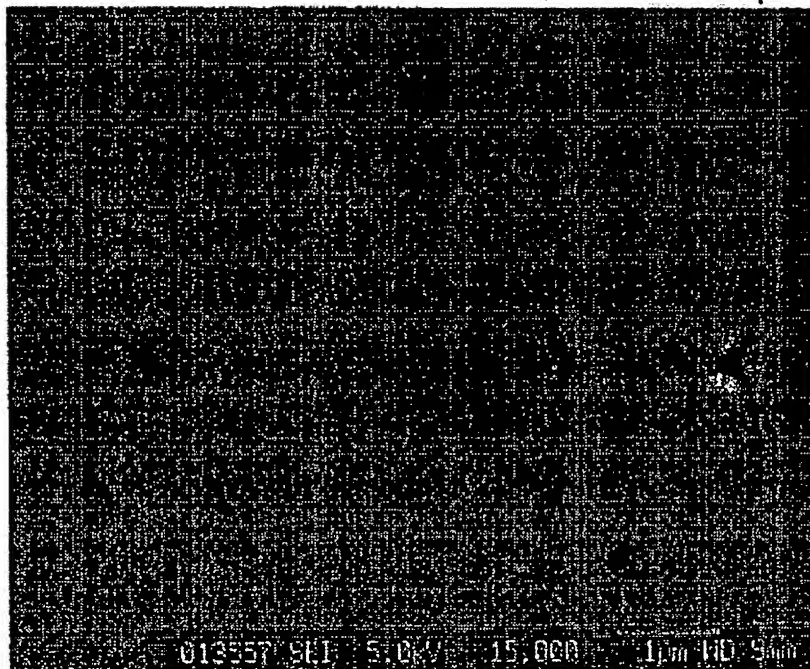
成膜前

Al/LT

クラック



(b)



成膜後

SiO<sub>2</sub>/Al/LT

[Translation done.]

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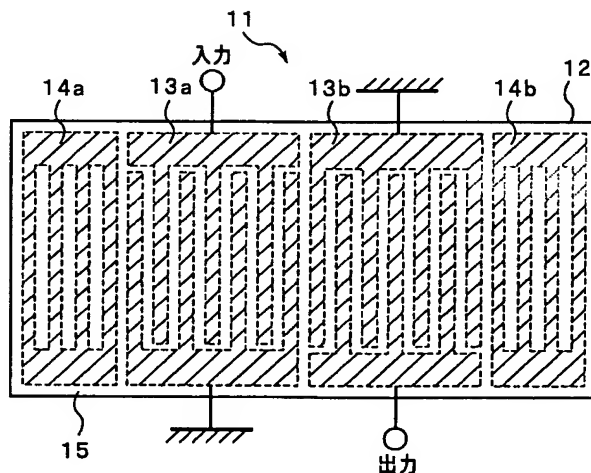
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FF05 GG03 KK01 KK05 KK06

(54) 【発明の名称】 弾性表面波装置

(57) 【要約】

【課題】 IDT上に $\text{SiO}_2$ 膜を形成することにより周波数温度特性が改善されているだけでなく、 $\text{SiO}_2$ 膜表面におけるクラックが生じ難く、所望とする特性を確実に得ることができ、電気機械結合係数が大きく、減衰定数 $\alpha$ 小さい弾性表面波装置を提供する。

【解決手段】  $23^\circ \sim 46^\circ$  回転Y板の $\text{LiTaO}_3$ 基板上に、Cuを主体とする少なくとも1つのIDTが形成されており、該IDTを覆うように、 $\text{LiTaO}_3$ 基板上に $\text{SiO}_2$ 膜が形成されている、弾性表面波装置。



## 【特許請求の範囲】

【請求項1】 オイラー角 ( $0 \pm 3^\circ$ ,  $113^\circ \sim 136^\circ$ ,  $0 \pm 3^\circ$ ) の  $\text{LiTaO}_3$  基板と、  
前記  $\text{LiTaO}_3$  基板上に形成されており、Cuを主体とする少なくとも1つのIDTと、  
前記IDTを覆うように前記  $\text{LiTaO}_3$  基板上に形成された  $\text{SiO}_2$  膜とを備えることを特徴とする、弾性表面波装置。

【請求項2】 前記IDTの表面波の波長で規格化された膜厚  $H/\lambda$  が  $0.01 \sim 0.08$  であり、  
前記  $\text{SiO}_2$  膜の表面波の波長で規格化された膜厚が  $0.15 \sim 0.40$  の範囲にある、請求項1に記載の弾性表面波装置。

【請求項3】 前記IDTの膜厚  $H/\lambda$  が  $0.01 \sim 0.08$  であり、前記  $\text{SiO}_2$  膜の規格化膜厚及び  $\text{LiTaO}_3$  基板のオイラー角が、下記に表される組み合わせのいずれかである、請求項1に記載の弾性表面波装置 \*

(a)  $0 < H/\lambda \leq 0.01$  のとき

$$\theta_{\min} = -139.713 \times h_s^3 + 43.07132 \times h_s^2 - 20.568011 \times h_s + 125.8314 \dots \text{式A}$$

(b)  $0.01 < H/\lambda \leq 0.03$  のとき

$$\theta_{\min} = -139.660 \times h_s^3 + 46.02985 \times h_s^2 - 21.141500 \times h_s + 127.4181 \dots \text{式B}$$

(c)  $0.03 < H/\lambda \leq 0.05$  のとき

$$\theta_{\min} = -139.607 \times h_s^3 + 48.98838 \times h_s^2 - 21.714900 \times h_s + 129.0048 \dots \text{式C}$$

(d)  $0.05 < H/\lambda \leq 0.07$  のとき

$$\theta_{\min} = -112.068 \times h_s^3 + 39.60355 \times h_s^2 - 21.186000 \times h_s + 129.9397 \dots \text{式D}$$

(e)  $0.07 < H/\lambda \leq 0.09$  のとき

$$\theta_{\min} = -126.954 \times h_s^3 + 67.40488 \times h_s^2 - 29.432000 \times h_s + 131.5686 \dots \text{式E}$$

【請求項5】 前記  $\text{SiO}_2$  の規格化膜厚及び  $\text{LiTaO}_3$  基板のオイラー角が、下記の表に示される組み合わせのいずれかである、請求項3に記載の弾性表面波装置。

【表2】

| $\text{SiO}_2$ 膜厚 | $\text{LiTaO}_3$ のオイラー角 |
|-------------------|-------------------------|
| 0.15~0.18         | (0, 117~125, 0)         |
| 0.18~0.23         | (0, 117~125, 0)         |
| 0.23~0.28         | (0, 115~125, 0)         |
| 0.28~0.33         | (0, 113~125, 0)         |
| 0.33~0.38         | (0, 113~125, 0)         |
| 0.38~0.40         | (0, 113~125, 0)         |

【請求項6】 弾性表面波として、SH波を主成分とする漏洩弾性表面波を用いることを特徴とする、請求項1~5のいずれかに記載の弾性表面波装置。

## 【発明の詳細な説明】

【0001】

【発明の属する技術分野】 本発明は、共振子や帯域フィルタなどに用いられる弾性表面波装置に関し、より詳細

\*置。

【表1】

| $\text{SiO}_2$ 膜厚 | $\text{LiTaO}_3$ のオイラー角 |
|-------------------|-------------------------|
| 0.15~0.18         | (0, 117~137, 0)         |
| 0.18~0.23         | (0, 117~136, 0)         |
| 0.23~0.28         | (0, 115~135, 0)         |
| 0.28~0.33         | (0, 113~133, 0)         |
| 0.33~0.38         | (0, 113~135, 0)         |
| 0.38~0.4          | (0, 113~132, 0)         |

【請求項4】  $\text{SiO}_2$  膜の規格化膜厚を  $h_s$  としたときに、前記オイラー角 (0,  $\theta$ , 0) の  $\theta$  が下記の式

(1) の範囲にあることを特徴とする、請求項3に記載の弾性表面波装置。

$$\theta_{\min} - 2^\circ < \theta \leq \theta_{\min} + 2^\circ \dots \text{式(1)}$$

但し、式(1)中、 $\theta_{\min}$  は、IDTの規格化膜厚  $H/\lambda$  が下記の(a)~(e)の範囲の場合、それぞれ下記の式A~Eで表される値である。

には、回転Y板X伝搬  $\text{LiTaO}_3$  基板を用いた弾性表面波装置及びその製造方法に関する。

【0002】

【従来の技術】 携帯電話などの移動体通信機において、RF段の帯域フィルタやデュプレクサとして、弾性表面波フィルタが用いられている。この種の弾性表面波フィルタとして、 $30^\circ \sim 50^\circ$  回転Y板X伝搬の  $\text{LiTaO}_3$  基板上に、AlからなるIDT (インターデジタルトランスデューサー) が形成されており、漏洩弾性波を利用した弾性表面波フィルタが実用化されている。

【0003】 しかしながら、この弾性表面波フィルタでは、周波数温度特性が  $-30 \sim -40 \text{ ppm}/^\circ\text{C}$  と悪く、その改善が求められていた。そこで、周波数温度特性を改善するために、 $30^\circ \sim 50^\circ$  回転Y板X伝搬  $\text{LiTaO}_3$  基板上にAlからなるIDTを形成した後、さらに  $\text{SiO}_2$  膜を積層した構造が提案されている。 $\text{SiO}_2$  膜を形成することにより、周波数温度特性が改善される。

【0004】

【発明が解決しようとする課題】ところで、AlからなるIDTを形成する場合、反射係数や電気機械結合係数 $K^2$ を大きくするために、IDTの電極膜厚 $H/\lambda$  ( $H$ は膜厚、 $\lambda$ は表面波の波長)は、0.08~0.10とかなり厚くされる。このように、AlからなるIDTがかなり厚くされているため、図18(a)に示されている部分において、周波数温度特性を改善するためにSiO<sub>2</sub>膜がその上に形成されると、図18(b)に示すように、SiO<sub>2</sub>膜において大きな段差が生じ、SiO<sub>2</sub>膜にクラックが生じることがあった。そのため、クラックの発生により、弾性表面波フィルタのフィルタ特性が悪化しがちであった。

【0005】加えて、AlからなるIDTの電極膜厚が厚いため、SiO<sub>2</sub>膜の形成によるIDTの電極表面の凹凸を被覆する効果が十分でなく、それによって、温度特性が十分に改善されないことがあった。

【0006】さらに、SiO<sub>2</sub>膜の形成により減衰定数が大きくなりフィルタ特性の劣化が生じた。本発明の目的は、上述した従来技術の現状に鑑み、回転Y板X伝搬のLiTaO<sub>3</sub>基板を用いた弾性表面波装置において、SiO<sub>2</sub>膜の形成により周波数温度特性を改善し得るだけでなく、IDTの電極膜厚を低減することができ、SiO<sub>2</sub>膜におけるクラックを防止することができると共に減衰定数も大幅に低減でき、従って目的とするフィルタ特性などの電気的特性を得ることができ、かつIDTにおける電気機械結合係数及び反射係数が十分な大きさとされる、弾性表面波装置及びその製造方法を提供することにある。

\*

| SiO <sub>2</sub> 膜厚 | LiTaO <sub>3</sub> のオイラー角 | より好ましくは         |
|---------------------|---------------------------|-----------------|
| 0.15~0.18           | (0, 117~137, 0)           | (0, 120~135, 0) |
| 0.18~0.23           | (0, 117~136, 0)           | (0, 118~133, 0) |
| 0.23~0.28           | (0, 115~135, 0)           | (0, 117~133, 0) |
| 0.28~0.33           | (0, 113~133, 0)           | (0, 115~132, 0) |
| 0.33~0.38           | (0, 113~135, 0)           | (0, 115~133, 0) |
| 0.38~0.4            | (0, 113~132, 0)           | (0, 115~130, 0) |

【0012】本発明のさらに別の特定局面では、前記SiO<sub>2</sub>の規格化膜厚を $h_s$ とすると、前記オイラー角 $(0, \theta, 0)$ の $\theta$ が下記の式(1)の範囲とされる。  
 $\theta_{\min} - 2^\circ < \theta \leq \theta_{\min} + 2^\circ$  …式(1)

(a)  $0 < H/\lambda \leq 0.01$ のとき

$$\theta_{\min} = -139.713 \times h_s^3 + 43.07132 \times h_s^2 - 20.568011 \times h_s + 125.8314 \dots \text{式A}$$

(b)  $0.01 < H/\lambda \leq 0.03$ のとき

$$\theta_{\min} = -139.660 \times h_s^3 + 46.02985 \times h_s^2 - 21.141500 \times h_s + 127.4181 \dots \text{式B}$$

(c)  $0.03 < H/\lambda \leq 0.05$ のとき

$$\theta_{\min} = -139.607 \times h_s^3 + 48.98838 \times h_s^2 - 21.714900 \times h_s + 129.0048 \dots \text{式C}$$

(d)  $0.05 < H/\lambda \leq 0.07$ のとき

$$\theta_{\min} = -112.068 \times h_s^3 + 39.60355 \times h_s^2$$

\*【0007】

【課題を解決するための手段】本発明の広い局面によれば、オイラー角 $(0 \pm 3^\circ, 113^\circ \sim 136^\circ, 0 \pm 3^\circ)$ のLiTaO<sub>3</sub>基板と、前記LiTaO<sub>3</sub>基板上に形成されており、Cuを主体とする少なくとも1つのIDTと、前記IDTを覆うように前記LiTaO<sub>3</sub>基板上に形成されたSiO<sub>2</sub>膜とを備えることを特徴とする、弾性表面波装置が提供される。

【0008】本発明においては、IDTがCuを主体とするため、かつ、SiO<sub>2</sub>膜が形成されているため、電気機械結合係数が大きくなり、かつ周波数温度特性が改善される。さらに、上記特定のオイラー角のLiTaO<sub>3</sub>基板が用いられるため、減衰定数 $\alpha$ が低減される。

【0009】本発明のより限定的な局面では、表面波の波長で規格化されたIDTの膜厚 $H/\lambda$ が0.01~0.08の範囲にあり、SiO<sub>2</sub>膜の表面波の波長で規格化された膜厚 $H/\lambda$ が0.15~0.40の範囲とされ、その場合には、本発明に従って、電気機械結合係数及び反射係数が大きく、良好な周波数温度特性を有し、減衰定数が十分に小さく、SiO<sub>2</sub>膜のクラックが生じ難い、弾性表面波装置を確実に提供することができる。

【0010】本発明のさらに他の局面では、前記IDTの膜厚 $H/\lambda$ が0.12以下であり、SiO<sub>2</sub>の規格化膜厚及び前記LiTaO<sub>3</sub>基板のオイラー角が、下記に表される組み合わせのいずれかとされる。

【0011】

【表3】

但し、式(1)中、 $\theta_{\min}$ は、IDTの規格化膜厚 $H/\lambda$ が下記の(a)~(e)の範囲にあるとき、それぞれ下記の式A~Eで表される値である。

$$-21.186000 \times h s + 129.9397 \cdots \text{式D}$$

(e)  $0.07 < H/\lambda \leq 0.09$  のとき

$$\theta_{\text{air}} = -126.954 \times h s^3 + 67.40488 \times h s^2$$

$$-29.432000 \times h s + 131.5686 \cdots \text{式E}$$

本発明のさらに他の特定の局面では、前記  $\text{SiO}_2$  の規格化膜厚及び  $\text{LiTaO}_3$  基板のオイラー角が、下記の表に示される組み合わせのいずれかとされる。

【0013】

【表4】

| $\text{SiO}_2$ 膜厚 | $\text{LiTaO}_3$ のオイラー角 |
|-------------------|-------------------------|
| 0.15~0.18         | (0, 117~125, 0)         |
| 0.18~0.23         | (0, 117~125, 0)         |
| 0.23~0.28         | (0, 115~125, 0)         |
| 0.28~0.33         | (0, 113~125, 0)         |
| 0.33~0.38         | (0, 113~125, 0)         |
| 0.38~0.40         | (0, 113~125, 0)         |

【0014】上記表に示す組み合わせの場合、すなわちオイラー角の  $\theta$  が  $125^\circ$  以下とされている場合には、電気機械結合係数  $K^2$  を一層大きくすることができる。本発明に係る弾性表面波装置では、好ましくは、表面波として漏洩弾性表面波が用いられ、本発明に従って、周波数温度特性に優れ、電気機械結合係数及び反射係数の大きな IDT を有する、伝搬損失の小さい、弾性表面波装置を提供することができる。

【0015】

【発明の実施の形態】以下、図面を参照しつつ、本発明の具体的な実施例を説明することにより、本発明を明らかにする。

【0016】図1は、本発明の一実施例に係る弾性表面波装置としての縦結合共振器フィルタを説明するための平面図である。弾性表面波装置11は、 $\text{LiTaO}_3$  基板12の上面に、IDT13a、13b及び反射器14a、14bを形成した構造を有する。また、IDT13a、13b及び反射器14a、14bを覆うように  $\text{SiO}_2$  膜15が形成されている。なお、 $\text{LiTaO}_3$  基板12としては、 $23^\circ \sim 46^\circ$  回転Y板  $\text{LiTaO}_3$  基板が用いられる。この範囲外のカット角の回転Y板X伝搬  $\text{LiTaO}_3$  基板では、減衰定数が大きく、TCFも悪化する。

【0017】IDT13a、13b及び反射器14a、14bは、Alに比べて密度の高いCuからなる。上記のように、Alに比べて密度の高いCuによりIDT13a、13b及び反射器14a、14bが構成されているため、IDT13a、13b及び反射器14a、14bの膜厚をAlを用いた場合に比べて薄くした場合であっても、電気機械結合係数及び反射係数を高めることができる。

【0018】図16は、 $\text{SiO}_2$  膜の規格化膜厚が0.20の場合のCu電極とAl電極の電極膜一本あたりの反射率と、電極膜厚との関係を示す図である。図16に示すように、従来用いられているAlからなる電極に比

べて、Cuからなる電極を用いた場合、電極指1本あたりの反射率が高められるため、反射器における電極指の本数も低減することができる。従って、反射器の小型化、ひいては表面波装置の小型化を図ることができる。

【0019】そして、上記のように電極膜厚を薄くすることができるので、IDT13a、13b上に形成された  $\text{SiO}_2$  膜15における前述した段差に基づくクラックの発生を確実に抑制することができる。 $\text{SiO}_2$  膜15の厚みについては、後述の実験例から明らかなように、表面波の波長で規格化された膜厚  $H/\lambda$  が0.15~0.40の範囲であることが好ましい。この範囲にすることで、 $\text{SiO}_2$  膜が形成されていない場合よりも減衰定数を大幅に小さくすることができ、低損失化が可能となる。

【0020】後述するように、IDT13a、13bの表面波の波長で規格化された膜厚  $H/\lambda$  は0.01~0.08が好ましい。本発明に係る弾性表面波装置では、上記のように、 $\text{LiTaO}_3$  基板12上にCuによりIDT13a、13bが構成されており、該IDT13a、13bの電極膜厚を薄くすることができる。従って、 $\text{SiO}_2$  膜における段差の発生を抑制することができ、クラックを確実に防止することができる。さらに上記特定のオイラー角の  $\text{LiTaO}_3$  基板を用いるため減衰定数を大幅に小さくすることができ、低ロス化が可能となる。また、 $\text{SiO}_2$  膜15の形成により、良好な周波数温度特性が実現される。これを、具体的な実験例に基づき説明する。

【0021】 $\text{LiTaO}_3$  基板を伝わる表面波には、レイリー波の他に漏洩弾性表面波(LSAW)がある。漏洩弾性表面波は、レイリー波に比べて音速が早く、電気機械結合係数が多いが、エネルギーを基板内に放射しつつ伝搬する。従って、漏洩弾性表面波は、伝搬ロスの原因となる減衰定数を有する。

【0022】図3は、回転Y板X伝搬  $\text{LiTaO}_3$  基板におけるオイラー角  $(0^\circ, \theta, 0^\circ)$  の  $\theta$  と、基板表面が電氣的に短絡された場合の減衰定数  $\alpha$  との関係を示す。なお、回転角  $= \theta - 90^\circ$  の関係がある。

【0023】図3から明らかなように、オイラー角の  $\theta$  が  $124^\circ \sim 126^\circ$  の範囲では、減衰定数  $\alpha$  は小さいが、この範囲外では減衰定数  $\alpha$  は大きくなることがわかる。また、比較的膜厚が厚いAlからなるIDTを用いた場合、 $\theta = 129^\circ \sim 136^\circ$  で減衰定数が小さくなることが知られている。従って、従来は、AlからなるIDTを用いる場合、 $\text{LiTaO}_3$  基板として、オイラー角の  $\theta$  が  $129^\circ \sim 136^\circ$  の範囲のものが用いられていた。



【0024】図2は、オイラー角の $\theta$ と電気機械結合係数 $K^2$ との関係を示す。図2から明らかなように、オイラー角の $\theta$ が $100^\circ \sim 120^\circ$ の範囲で、大きな電気機械結合係数 $K^2$ が得られる。しかしながら、図3から明らかなように、 $\theta = 100^\circ \sim 120^\circ$ の範囲では減衰定数 $\alpha$ が大きく、 $\theta = 100^\circ \sim 120^\circ$ のLiTaO<sub>3</sub>基板は弾性表面波装置に使用することはできない。

【0025】図4は、 $36^\circ$ 回転Y板X伝搬LiTaO<sub>3</sub>基板（オイラー角で $(0^\circ, 126^\circ, 0^\circ)$ ）上に、CuからなるIDTを形成した場合のCu膜の規格化膜厚 $H/\lambda$ と、電気機械結合係数 $K^2$ との関係を示す。なお、 $\lambda$ は、弾性表面波装置の中心周波数における波長を示すものとする。

【0026】図4から明らかなように、Cu膜の膜厚 $H/\lambda$ が $0.01 \sim 0.10$ の範囲において、電気機械結合係数 $K^2$ が、Cu膜が形成されていない場合（ $H/\lambda = 0$ ）に比べて1.5倍以上となることがわかる。また、Cu膜の膜厚が $H/\lambda = 0.02 \sim 0.08$ の範囲では、Cu膜が形成されていない場合に比べて、電気機械結合係数 $K^2$ は1.8倍以上の値となり、Cu膜の膜厚 $H/\lambda$ が $0.03 \sim 0.06$ の範囲では、Cu膜が形成されていない場合の2倍以上の値となることがわかる。さらに、従来用いられるA1と比較して $H/\lambda$ が $0.04$ 程度と薄い膜厚で極大値をとり、その値もA1に比べて大きい。

【0027】Cu膜の規格化膜厚 $H/\lambda$ が $0.08$ を超えると、Cu膜からなるIDTの作製が困難となる。従って、大きな電気機械結合係数を得ることができ、かつIDTの作製が容易であるため、Cu膜からなるIDTの厚みは、 $0.01 \sim 0.08$ の範囲であることが望ましく、より好ましくは $0.02 \sim 0.08$ 、さらに好ましくは $0.03 \sim 0.06$ の範囲とされる。

【0028】次に、LiTaO<sub>3</sub>基板上に、SiO<sub>2</sub>膜を成膜した場合の周波数温度係数TCFの変化を図5に示す。図5は、オイラー角 $(0^\circ, 113^\circ, 0^\circ)$ 、 $(0^\circ, 126^\circ, 0^\circ)$ 及び $(0^\circ, 129^\circ, 0^\circ)$ の3種類のLiTaO<sub>3</sub>基板上にSiO<sub>2</sub>膜が形成されている場合のSiO<sub>2</sub>膜の規格化膜厚 $H/\lambda$ とTCFとの関係を示す。なお、ここでは電極は形成されていない。

【0029】図5から明らかなように、 $\theta$ が $113^\circ$ 、 $126^\circ$ 及び $129^\circ$ のいずれの場合においても、SiO<sub>2</sub>膜の規格化膜厚 $H/\lambda$ が $0.15 \sim 0.45$ の範囲において、TCFが $-20 \sim +17 \text{ ppm}/^\circ\text{C}$ の範囲となることがわかる。もっとも、SiO<sub>2</sub>膜の成膜には時間を要するため、SiO<sub>2</sub>膜の膜厚 $H/\lambda$ は $0.15 \sim$

$0.40$ が望ましい。

【0030】LiTaO<sub>3</sub>基板上にSiO<sub>2</sub>膜を成膜することにより、レイリー波などのTCFが改善されることは知られていたが、LiTaO<sub>3</sub>基板上に、Cuからなる電極を形成し、さらにSiO<sub>2</sub>膜を積層した構造において、実際に、Cuからなる電極の膜厚、SiO<sub>2</sub>の膜厚、カット角、及び漏洩弾性波の減衰定数を考慮して実験された報告はない。

【0031】図6は、オイラー角 $(0^\circ, 120^\circ, 0^\circ)$ のLiTaO<sub>3</sub>基板上に規格化膜厚 $H/\lambda$ が $0.1$ 以下のCuからなる電極と、規格化膜厚 $H/\lambda$ が $0 \sim 0.5$ のSiO<sub>2</sub>膜を形成した場合における減衰定数 $\alpha$ の変化を示す。図6から明らかなように、SiO<sub>2</sub>膜の膜厚 $H/\lambda$ が $0.2 \sim 0.40$ 、Cu膜の膜厚 $H/\lambda$ が $0.01 \sim 0.10$ である場合に減衰定数 $\alpha$ が小さくなっていることがわかる。

【0032】他方、図7は、 $(0^\circ, 135^\circ, 0^\circ)$ のオイラー角のLiTaO<sub>3</sub>基板上には、規格化膜厚 $H/\lambda$ が $0 \sim 0.10$ のCu膜を形成し、さらに、規格化膜厚 $H/\lambda$ が $0 \sim 0.5$ のSiO<sub>2</sub>膜を形成した場合の減衰定数 $\alpha$ の変化を示す。

【0033】図7から明らかなように、 $\theta = 135^\circ$ のLiTaO<sub>3</sub>基板を用いた場合には、Cu膜の膜厚及びSiO<sub>2</sub>膜の膜厚を上記のように変化させたとしても、減衰定数 $\alpha$ は大きいことがわかる。

【0034】すなわち、良好なTCF、大きな電気機械結合係数及び小さな減衰定数を実現するには、LiTaO<sub>3</sub>基板のカット角すなわちオイラー角と、SiO<sub>2</sub>膜の膜厚と、Cuからなる電極の膜厚とをそれぞれ最適のように組み合わせることが必要となることがわかる。

【0035】図8～図15は、それぞれ、SiO<sub>2</sub>膜の規格化膜厚 $H/\lambda$ が、 $0.1$ 、 $0.15$ 、 $0.2$ 、 $0.25$ 、 $0.3$ 、 $0.35$ 、 $0.4$ または $0.45$ であり、規格化膜厚 $H/\lambda$ が $0.08$ 以下のCu膜をLiTaO<sub>3</sub>基板上に形成した場合の $\theta$ と減衰定数 $\alpha$ との関係を示す。

【0036】図8～図15から明らかなように、Cu膜の厚み $H/\lambda$ を $0.01 \sim 0.08$ とした場合、SiO<sub>2</sub>膜の厚みと、オイラー角の $\theta$ とが、下記の表5に示すように選択されれば、周波数温度特性TCFが良好であり、電気機械結合係数が大きく、かつ減衰定数 $\alpha$ を効果的に抑制し得ることがわかる。望ましくは、下記の表3の右側のより好ましいオイラー角を選択することにより、より一層良好な特性を得ることができる。

【0037】

【表5】

| SiO <sub>2</sub> 膜厚 | LiTaO <sub>3</sub> のオイラー角 | より好ましくは         |
|---------------------|---------------------------|-----------------|
| 0.15~0.18           | (0, 117~137, 0)           | (0, 120~135, 0) |
| 0.18~0.23           | (0, 117~136, 0)           | (0, 118~133, 0) |
| 0.23~0.28           | (0, 115~135, 0)           | (0, 117~133, 0) |
| 0.28~0.33           | (0, 113~133, 0)           | (0, 115~132, 0) |
| 0.33~0.38           | (0, 113~135, 0)           | (0, 115~133, 0) |
| 0.38~0.4            | (0, 113~132, 0)           | (0, 115~130, 0) |

【0038】また、図2から明らかなように、オイラー角の $\theta$ が $125^\circ$ 以下になると、電気機械結合係数 $k^2$ が著しく大きくなることがわかる。従って、より好ましくは、下記の表6に示すSiO<sub>2</sub>膜の規格化膜厚とオイ

ラー角との組み合わせが望ましいことがわかる。

【0039】

【表6】

| SiO <sub>2</sub> 膜厚 | LiTaO <sub>3</sub> のオイラー角 |
|---------------------|---------------------------|
| 0.15~0.18           | (0, 117~125, 0)           |
| 0.18~0.23           | (0, 117~125, 0)           |
| 0.23~0.28           | (0, 115~125, 0)           |
| 0.28~0.33           | (0, 113~125, 0)           |
| 0.33~0.38           | (0, 113~125, 0)           |
| 0.38~0.40           | (0, 113~125, 0)           |

\* 【0040】さらに、図5~図14に示した結果から、減衰定数が0もしくは最小となるオイラー角、すなわち $\theta_{\min}$ を、SiO<sub>2</sub>膜の規格化膜厚 $hs$ 及びCu膜の規格化膜厚 $H/\lambda$ に対して求めた結果を、図17に示す。

【0041】Cu膜の規格化膜厚 $H/\lambda$ が、0、0.02、0.04、0.06及び0.08の場合の図17に示す各曲線を三次式で近似することにより、下記の式A~Eが得られる。

\*

(a)  $0 < H/\lambda \leq 0.01$  のとき

$$\theta_{\min} = -139.713 \times hs^3 + 43.07132 \times hs^2 - 20.568011 \times hs + 125.8314 \dots \text{式A}$$

(b)  $0.01 < H/\lambda \leq 0.03$  のとき

$$\theta_{\min} = -139.660 \times hs^3 + 46.02985 \times hs^2 - 21.141500 \times hs + 127.4181 \dots \text{式B}$$

(c)  $0.03 < H/\lambda \leq 0.05$  のとき

$$\theta_{\min} = -139.607 \times hs^3 + 48.98838 \times hs^2 - 21.714900 \times hs + 129.0048 \dots \text{式C}$$

(d)  $0.05 < H/\lambda \leq 0.07$  のとき

$$\theta_{\min} = -112.068 \times hs^3 + 39.60355 \times hs^2 - 21.186000 \times hs + 129.9397 \dots \text{式D}$$

(e)  $0.07 < H/\lambda \leq 0.09$  のとき

$$\theta_{\min} = -126.954 \times hs^3 + 67.40488 \times hs^2 - 29.432000 \times hs + 131.5686 \dots \text{式E}$$

従って、好ましくは、オイラー角 $(0, \theta, 0)$ の $\theta$ は、上述した式A~式Eで示される $\theta_{\min}$ とされることが望ましいが、 $\theta_{\min} - 2^\circ < \theta \leq \theta_{\min} + 2^\circ$ であれば、減衰定数を効果的に小さくすることができる。

【0042】なお、本発明ではIDTはCuのみから構成されてもよいが、Cuを主体とする限り、Cu合金やCuと他の金属との積層体で構成されてもよい。Cuを主体とするIDTとは、電極の平均密度を $\rho$ （平均）とすると

$$\rho(\text{Cu}) \times 0.7 \leq \rho(\text{平均}) \leq \rho(\text{Cu}) \times 1.3$$

すなわち、

$$6.25 \text{ g/cm}^3 \leq \rho(\text{平均}) \leq 11.6 \text{ g/cm}^3$$

を満足するものであればよい。なお、Cuの上あるいは下に電極全体の $\rho$ （平均）が上記範囲となるように、Alよりも密度の大きいW、Ta、Au、Pt、AgまたはCrなどの金属からなる電極を積層してもよい。その

場合にも、Cu電極単層の場合と同様の効果が得られる。

【0043】上記実験では、オイラー角 $(0^\circ, \theta, 0^\circ)$ のLiTaO<sub>3</sub>基板が用いられたが、基板材料のオイラー角において、 $0 \pm 3^\circ$ のばらつきが通常発生する。このようなばらつきの範囲内、すなわち $(0 \pm 3^\circ, 113^\circ \sim 136^\circ, 0 \pm 3^\circ)$ のLiTaO<sub>3</sub>基板においても、本発明の効果は得られる。

【0044】なお、本発明は、図1に示した縦結合共振子型弾性表面波フィルタだけでなく、弾性表面波共振子、横結合型表面波フィルタ、ラダー型フィルタ、ラチス型フィルタなどの様々な表面波装置に適用することができる。

【0045】

【発明の効果】本発明に係る弾性表面波装置では、オイラー角 $(0 \pm 3^\circ, 113^\circ \sim 136^\circ, 0 \pm 3^\circ)$ の

LiTaO<sub>3</sub>基板上に、Cuを主体とする少なくとも1つのIDTが形成されており、該IDTを覆うようにLiTaO<sub>3</sub>基板上にSiO<sub>2</sub>膜が形成されているため、電気機械結合係数が大きく、温度特性に優れており、かつ減衰定数 $\alpha$ が低減された、伝搬損失が少ない弾性表面波装置を提供することができる。

【0046】また、本発明において、IDTの表面波の波長で規格化された膜厚が0.01~0.08であり、SiO<sub>2</sub>膜の規格化膜厚が0.15~0.40の範囲にある場合には、電気機械結合係数をより一層高めることができ、かつ良好な温度特性を実現することができる。

【0047】さらに、IDTの膜厚 $H/\lambda$ が0.01~0.08であり、表1、より好ましくは表2に示すように、LiTaO<sub>3</sub>基板のオイラー角の $\theta$ 及びSiO<sub>2</sub>膜の規格化膜厚 $H/\lambda$ が選ばれている場合には、より一層、電気機械結合係数が大きく、減衰定数 $\alpha$ が小さく、さらに周波数温度特性に優れた弾性表面波装置を提供することができる。

【0048】また、LiTaO<sub>3</sub>基板のオイラー角 $(0, \theta, 0)$ の $\theta$ が $\theta_{min} - 2^\circ$ より大であり、 $\theta_{min} + 2^\circ$ 以下の場合には、減衰定数がより一層小さくされる。従って、伝搬損失がより一層小さくされ得る。

【図面の簡単な説明】

【図1】本発明の一実施例に係る弾性表面波装置を示す平面図。

【図2】オイラー角 $(0^\circ, \theta, 0^\circ)$ のLiTaO<sub>3</sub>基板上における $\theta$ と電気機械結合係数 $K^2$ との関係を示す図。

【図3】オイラー角 $(0^\circ, \theta, 0^\circ)$ のLiTaO<sub>3</sub>基板上における $\theta$ と減衰定数 $\alpha$ との関係を示す図。

【図4】オイラー角 $(0^\circ, 126^\circ, 0^\circ)$ のLiTaO<sub>3</sub>基板上に、種々の膜厚のCuまたはAl膜からなる電極を形成した場合のCuまたはAl膜の規格化膜厚 $H/\lambda$ と、電気機械結合係数 $K^2$ との関係を示す図。

【図5】オイラー角 $(0^\circ, 113^\circ, 0^\circ)$ 、 $(0^\circ, 126^\circ, 0^\circ)$ 及び $(0^\circ, 129^\circ, 0^\circ)$ の3種類のLiTaO<sub>3</sub>基板において、電極を形成せずに、種々の膜厚のSiO<sub>2</sub>膜を成膜した場合のSiO<sub>2</sub>膜の規格化膜厚 $H/\lambda$ と周波数温度係数TCFとの関係を示す図。

【図6】オイラー角 $(0^\circ, 120^\circ, 0^\circ)$ のLiTaO<sub>3</sub>基板上に、0.1以下の規格化膜厚のCu膜を形成し、0~0.5の規格化膜厚のSiO<sub>2</sub>膜を成膜した場合の減衰定数 $\alpha$ の変化を示す図。

【図7】オイラー角 $(0^\circ, 135^\circ, 0^\circ)$ のLiTaO<sub>3</sub>基板上に、0.1以下の規格化膜厚のCu膜を形成し、0~0.5の規格化膜厚のSiO<sub>2</sub>膜を成膜した場合の減衰定数 $\alpha$ の変化を示す図。

【図8】オイラー角 $(0^\circ, \theta, 0^\circ)$ のLiTaO<sub>3</sub>基板上に、規格化膜厚 $H/\lambda$ が0.1以下の各種Cu膜を形成し、規格化膜厚 $H/\lambda$ が0.1のSiO<sub>2</sub>膜を積層した場合の、減衰定数 $\alpha$ の変化を示す図。

【図9】オイラー角 $(0^\circ, \theta, 0^\circ)$ のLiTaO<sub>3</sub>基板上に、規格化膜厚 $H/\lambda$ が0.1以下の各種Cu膜を形成し、規格化膜厚 $H/\lambda$ が0.15のSiO<sub>2</sub>膜を積層した場合の、減衰定数 $\alpha$ の変化を示す図。

【図10】オイラー角 $(0^\circ, \theta, 0^\circ)$ のLiTaO<sub>3</sub>基板上に、規格化膜厚 $H/\lambda$ が0.1以下の各種Cu膜を形成し、規格化膜厚 $H/\lambda$ が0.2のSiO<sub>2</sub>膜を積層した場合の、減衰定数 $\alpha$ の変化を示す図。

【図11】オイラー角 $(0^\circ, \theta, 0^\circ)$ のLiTaO<sub>3</sub>基板上に、規格化膜厚 $H/\lambda$ が0.1以下の各種Cu膜を形成し、規格化膜厚 $H/\lambda$ が0.25のSiO<sub>2</sub>膜を積層した場合の、減衰定数 $\alpha$ の変化を示す図。

【図12】オイラー角 $(0^\circ, \theta, 0^\circ)$ のLiTaO<sub>3</sub>基板上に、規格化膜厚 $H/\lambda$ が0.1以下の各種Cu膜を形成し、規格化膜厚 $H/\lambda$ が0.3のSiO<sub>2</sub>膜を積層した場合の、減衰定数 $\alpha$ の変化を示す図。

【図13】オイラー角 $(0^\circ, \theta, 0^\circ)$ のLiTaO<sub>3</sub>基板上に、規格化膜厚 $H/\lambda$ が0.1以下の各種Cu膜を形成し、規格化膜厚 $H/\lambda$ が0.35のSiO<sub>2</sub>膜を積層した場合の、減衰定数 $\alpha$ の変化を示す図。

【図14】オイラー角 $(0^\circ, \theta, 0^\circ)$ のLiTaO<sub>3</sub>基板上に、規格化膜厚 $H/\lambda$ が0.1以下の各種Cu膜を形成し、規格化膜厚 $H/\lambda$ が0.4のSiO<sub>2</sub>膜を積層した場合の、減衰定数 $\alpha$ の変化を示す図。

【図15】オイラー角 $(0^\circ, \theta, 0^\circ)$ のLiTaO<sub>3</sub>基板上に、規格化膜厚 $H/\lambda$ が0.1以下の各種Cu膜を形成し、規格化膜厚 $H/\lambda$ が0.45のSiO<sub>2</sub>膜を積層した場合の、減衰定数 $\alpha$ の変化を示す図。

【図16】SiO<sub>2</sub>膜の規格化膜厚が0.02のときのAlからなる電極及びCuからなる電極における電極指1本当たりの反射率と電極膜厚との関係を示す図。

【図17】減衰定数が0もしくは最小となる $\theta_{min}$ を実現するためのSiO<sub>2</sub>膜の規格化膜厚 $H_s/\lambda$ と、Cu膜の規格化膜厚 $H/\lambda$ との関係を示す図。

【図18】(a)及び(b)は、従来の弾性表面波装置の問題点を説明するための図であり、SiO<sub>2</sub>膜の成膜前(a)と、成膜後(b)のSiO<sub>2</sub>膜の表面の状態を示す走査型電子顕微鏡写真を示す図。

【符号の説明】

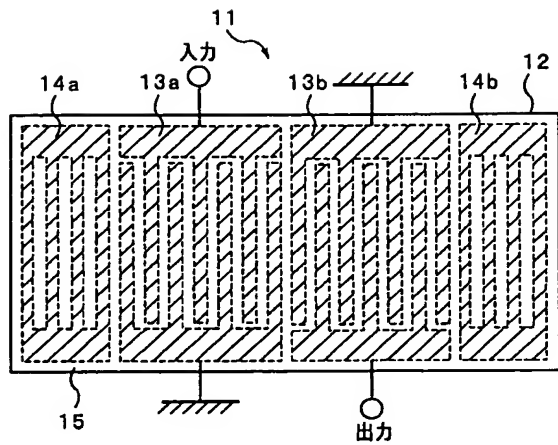
11…弾性表面波装置

12…LiTaO<sub>3</sub>基板

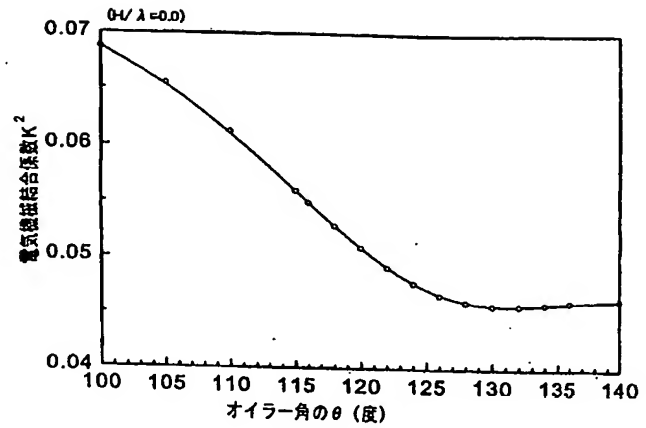
13a, 13b…IDT

15…SiO<sub>2</sub>膜

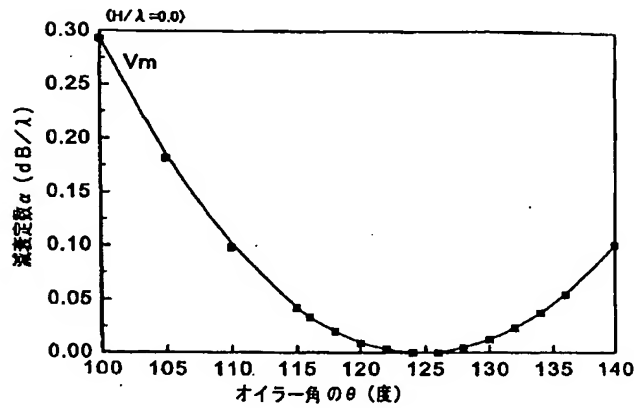
【図1】



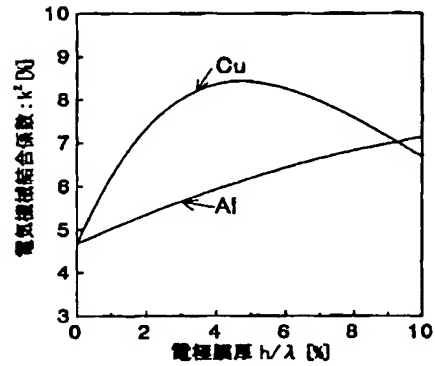
【図2】



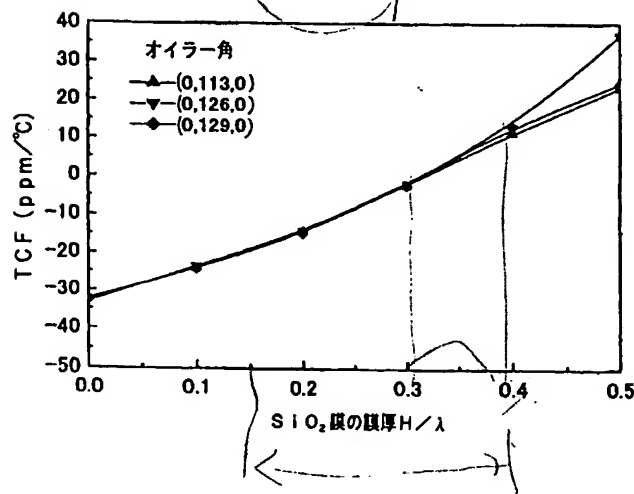
【図3】



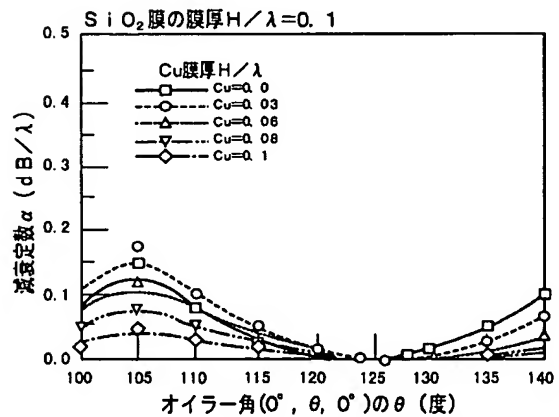
【図4】



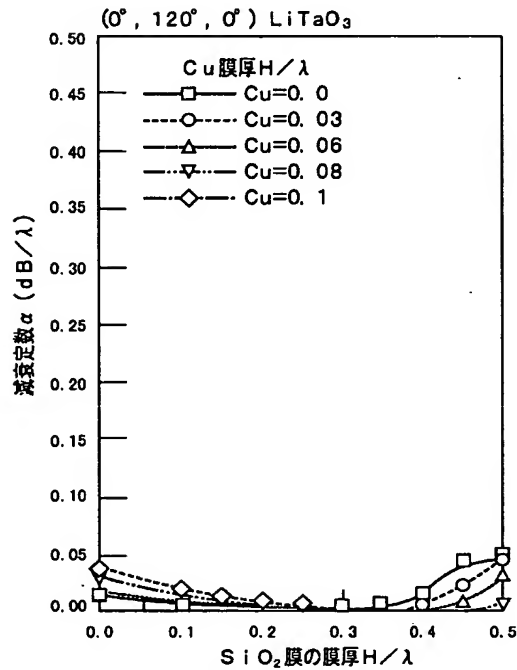
【図5】



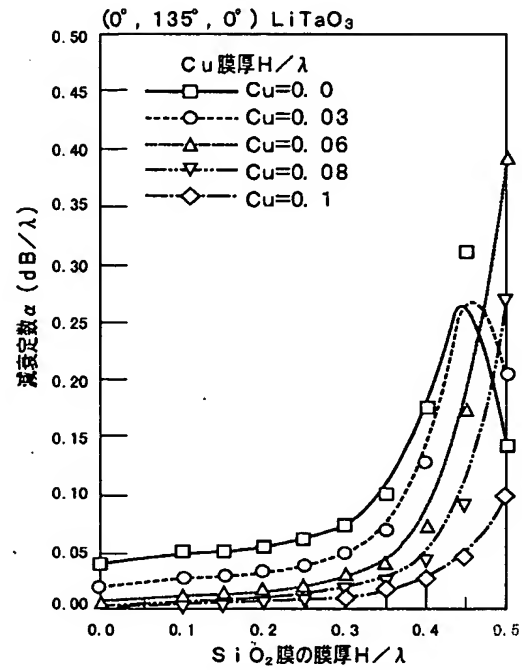
【図8】



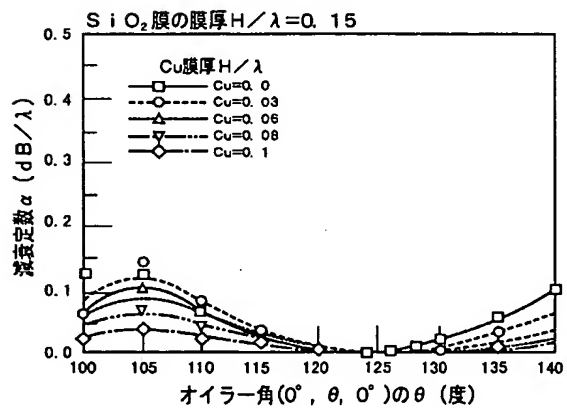
【図6】



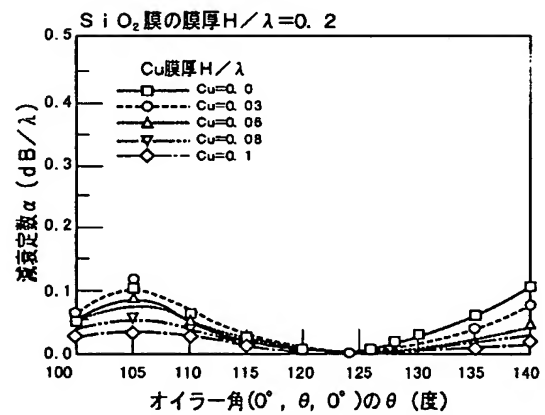
【図7】



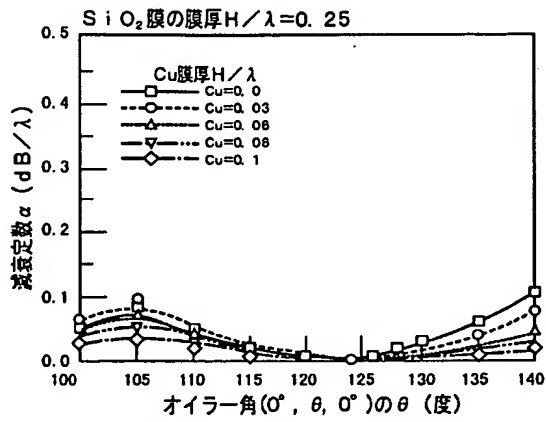
【図9】



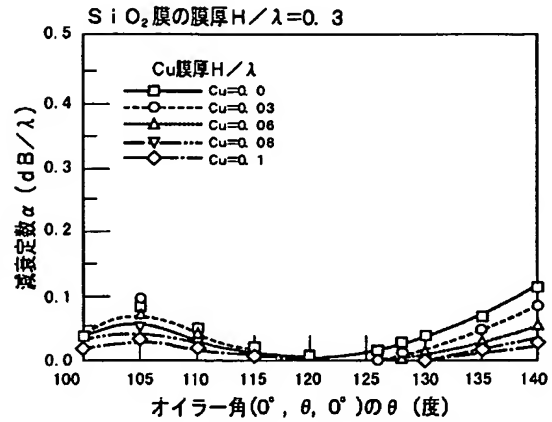
【図10】



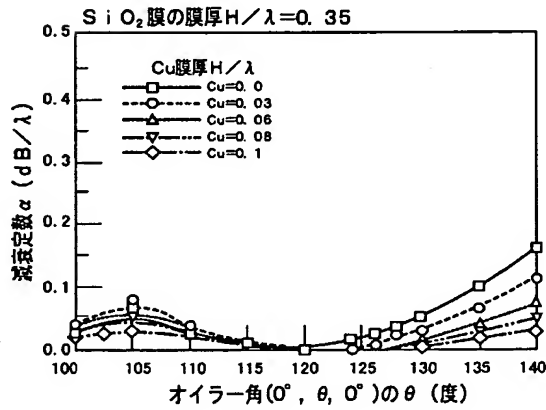
【図 11】



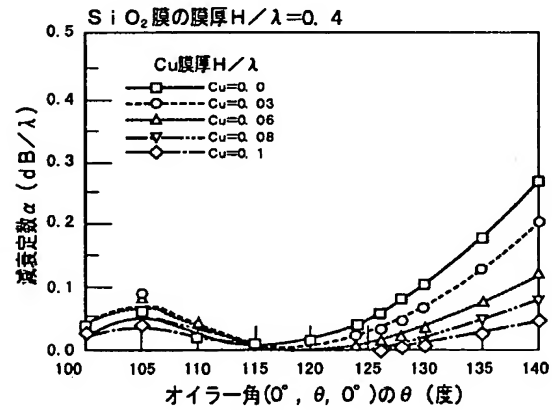
【図 12】



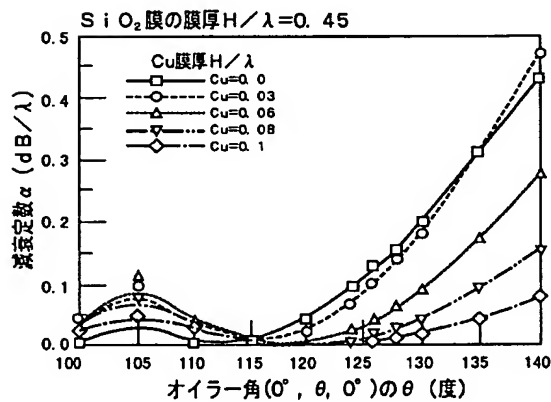
【図 13】



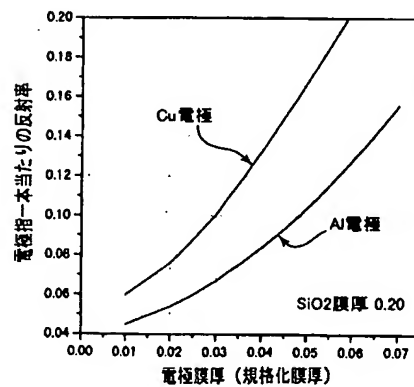
【図 14】



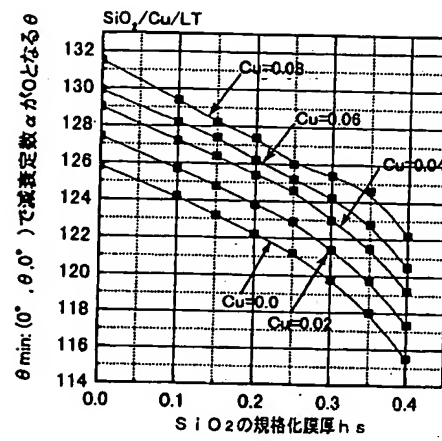
【図 15】



【図 16】

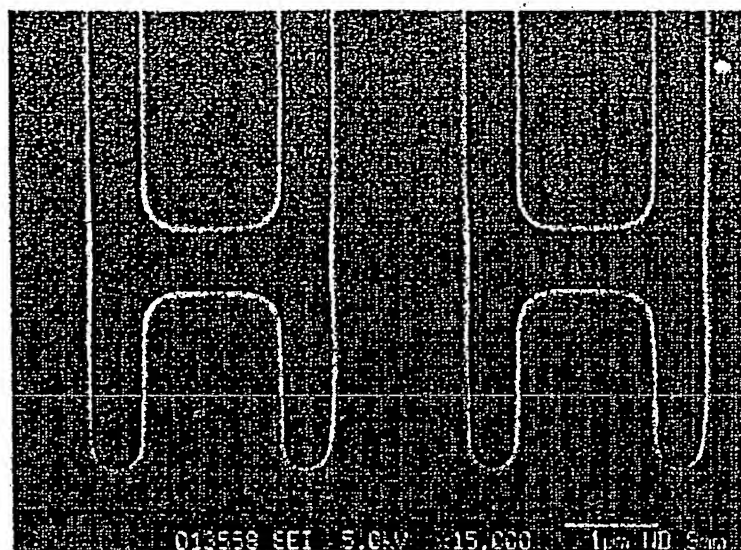


【図17】



【図18】

(a)

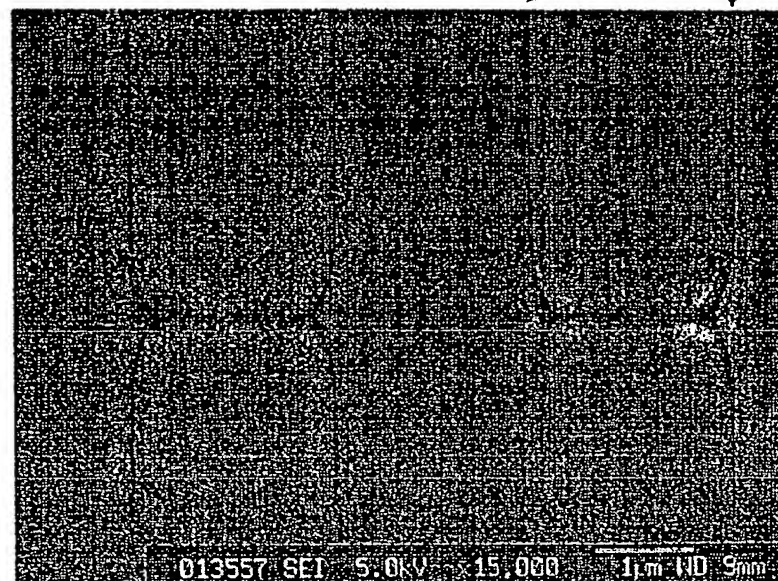


成膜前

Al/LT

クラック

(b)



成膜後

 $\text{SiO}_2/\text{Al/LT}$



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